The Missouri River Ecosystem: Exploring the Prospects for Recovery

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

Two hundred years ago, Lewis and Clark led their 'Corps of Discovery' on an unprecedented expedition to explore the vast dimensions of the nation's longest and largest river basin—the Missouri. Their central charge was to seek a water route to the Pacific Ocean to support commerce and development. Since those early days, the Missouri River and its tributaries have occupied a unique place in United States history. Like many of the nation's major river systems in the nineteenth and early twentieth centuries, the Missouri was viewed as a river to be controlled for purposes of human settlement and as a resource to support economic development. The Missouri River's water development hallmark was the Pick–Sloan Plan, which mandated the construction of a set of vast engineering projects aimed at controlling floods, facilitating navigation and commerce, and inducing agriculture and other forms of economic development in the Missouri Basin.

While many of society's goals were accomplished through the Pick–Sloan Plan, the Pick–Sloan vision was not fully realized. Much of the agricultural and commercial development—including navigation—has not reached anticipated levels of development because of several reasons: shifting economic conditions, a harsh climate in many sections of the basin, and decreasing enthusiasm for large-scale water development projects in the United States. Population growth in the basin has been modest compared to many areas of the U.S. and census data portray a demographic trend of people moving away from the basin's rural areas, with modest population growth in its cities. Just as Lewis and Clark never found an easily-traversed water route to the Pacific Ocean, a clear, consensus vision of the future Missouri River basin remains elusive. Among the challenges in finding that course is determining the appropriate roles for the symbolic heart of the basin—the Big Muddy.

Our committee extends its gratitude to the study sponsors, the EPA and the Corps of Engineers. Jim Berkley and Ian Schmitt of EPA (Denver) and Rose Hargrave of the Corps of Engineers (Omaha) are to be commended for their courage and vision in requesting the advice of the National Research Council regarding the condition and the adaptive management of the Missouri River ecosystem. Without their support and encouragement, this study would not have been possible.

In our meetings we sought and received input from many organizations and individuals with deep knowledge of the basin. The committee expresses its appreciation for the information and personal thoughts of many who helped shape its understanding and perception of the Missouri River. Input from local, state, and federal government officials and scientists,

representatives of conservation and environmental organizations, trade groups, agriculturists, businesses, Native Americans, and others—too numerous to mention by name—were instrumental in informing our committee's discussions about the Missouri River. Committee members also made numerous, enjoyable personal contacts with people in the basin from many walks of life, which enhanced our knowledge of the relations between people and the environment along the Missouri River. We also reviewed the extensive published literature dealing with the Missouri and large rivers in general. Much of our report contains the reflections of our findings from that literature. The enormity of the system and the diversity of its peoples and issues challenged us. Yet, through vigorous discussion and sharing of ideas, this committee came to a strong consensus about the state of the Missouri River ecosystem and ways in which its rich natural heritage might be restored and preserved, at least in part, for the next two hundred years of American history. I am personally grateful for the privilege of chairing a committee whose members demonstrated not only impressive scientific knowledge but a sensitivity to the articulation of that science with policy, a sincere interest in our charge, and high degree of civility and camaraderie.

This report also reflects the dedication and diligent work of the NRC staff. The committee, and I as chair, wish to particularly thank Senior Staff Officer Jeffrey Jacobs of the NRC's Water Science and Technology Board. Jeff's clear thinking and guidance to the committee on matters of substance as well as procedure are reflected in the quality of this report. We also thank Anike Johnson for her able handling of logistics for our meetings and the mechanics of integrating material for the report. Jon Sanders provided able editorial support during the final stages of the report's review. In addition to the NRC staff, Rhonda Bitterli provided excellent editorial advice on the committee's draft report.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise in accordance with the procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report: Barry Gold, U.S. Geological Survey; Lance Gunderson, Emory University; Lynne Lewis, Bates College; Diane McKnight, University of Colorado; Brian Richter, The Nature Conservancy; John Thorson, attorney and water policy consultant, Oakland, California; and M. Gordon Wolman, Johns Hopkins University.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Debra Knopman of RAND. Appointed by the National Research Council, she was responsible for making certain that an independent examination of the report was carefully carried out in accordance with the institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Today, the nation and the institutions and citizens in the Missouri Basin are embarking on another journey of discovery. In some ways, this journey resembles Lewis and Clark's expedition of two hundred years ago, in that stakeholders in the Missouri Basin will be challenged to explore the unknown and seek ways to ensure the most complete understanding and best use for America of one of her great rivers. We wish them luck and hope this report assists them in charting their course.

Steven P. Gloss, Chair

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Executive Summary

Over the past century, human activities have caused substantial ecological changes to the Missouri River ecosystem. By any measure, the Missouri River ecosystem—the Missouri River's main channel and its floodplain—has experienced significant reductions in natural habitat and in the abundance of native species and communities. There have also been substantial reductions in the daily and annual variability of hydrologic and geomorphic processes. Causes of these changes include the removal of snags from the river in the late 1800s; introduction of nonnative fish species beginning in the late 1800s; navigation enhancement beginning in the early 1900s; and damming and flow regulation of the mainstem Missouri River beginning in the 1930s. Land use changes (including urbanization, agriculture, transportation infrastructure) and population growth have also affected the ecosystem in less direct but important ways.

River systems have often proved remarkably resilient, withstanding a variety of human modifications and still responding positively to ecosystem restoration efforts. Strategies for improving ecological conditions in large river systems are relatively new, but some smaller rivers have exhibited rapid and positive ecological responses. In the Kissimmee River in Florida, for example, plant communities, fish, and invertebrates responded favorably to water-level manipulation experiments in the early 1980s. More recently, the breaching of Edwards Dam on Maine's Kennebec River in 1999 resulted in increases in the abundance of select bird and fish species. Nonetheless, there is a point beyond which a large, degraded river system can only be recovered with costly remediation efforts. Some losses—such as species extinction—can never be restored.

Given the size and complexity of the Missouri River ecosystem, it is not clear where the point of irreparable environmental change lies, or how close the Missouri River ecosystem might be to passing that point. However, the following changes in the Missouri River ecosystem jeopardize its fundamental natural processes: the loss of natural flood pulses; the loss of natural low flows; straightening of stream meanders and the elimination of cut-and-fill alluviation; losses of natural riparian vegetation; reductions in water temperature variation; introduction of nonnative species; and extensive bank stabilization and stream channelization. Specific examples of twentieth century changes in the Missouri River ecosystem include the following:

- Nearly 3 million acres of natural riverine and floodplain habitat (bluff to bluff along the Missouri River's mainstem) have been altered through land-use changes, inundation, channelization, and levee building.
- Sediment transport, which was the hallmark of the pre-regulation Missouri River (and was thus nicknamed "The Big Muddy"), has been dramatically reduced. Sediment transport and deposition was critical to maintaining the river system's form and dynamics. For example, before the 1950s, the Missouri River carried an average of roughly 142 million tons of sediment per year past Sioux City, Iowa; after closure of the dams, an average of roughly 4 million tons per year moved past the same location.
- Damming and channelization have occurred on most of the Missouri River basin's numerous tributary streams, where at least 75 dams have been constructed.
- The amplitude and the frequency of the Missouri River's natural peak flows have been sharply reduced. With the occasional exception of downstream sections in the state of Missouri, the Missouri River no longer experiences natural spring and summer rises and ecologically-beneficial low flows at other times of the year.
- Cropland expansion and reservoir impoundment have caused reductions in natural vegetation communities. These vegetation communities continue to shrink with the additional clearing of floodplain lands. The remaining remnant areas will be critical in any efforts to repopulate the floodplain ecosystem.
- Reproduction of cottonwoods, historically the most abundant and ecologically important species on the river's extensive floodplain, has largely ceased along the Missouri River, except in downstream reaches that were flooded in the 1990s.
- Production of benthic invertebrates (e.g., species of caddisfly and mayfly) has been reduced by approximately 70 percent in remnant unchannelized river reaches. Benthic invertebrates are an important food source for the river's native fishes and an important component of the river's food web.
- Of the 67 native fish species living along the mainstem, 51 are now listed as rare, uncommon, and/or decreasing across all or part of their ranges. One of these fishes (pallid sturgeon) and two avian species (least tern and piping plover) are on the federal Endangered Species List.
- In many reaches of the river, nonnative sport fishes exist in greater abundance than native fish species. The nonnative fishes are often more tolerant of altered conditions of temperature, turbidity, and habitat. Although some nonnative fish produce substantial economic benefits, nonnative species may also contribute to the declining abundance of native fish.

These ecosystem changes are not merely abstract, scientific measurements; they also represent the loss of valued goods and services to society. Examples of ecosystem goods and services include outdoor recreation, biomass fuels, wild game, timber, clean air and water, medicines, species richness, maintenance of soil fertility, and the natural recharge of groundwater. It is often difficult to recognize the economic values that are lost with declines of these ecosystem benefits, largely because they have historically not been carefully measured. But ecosystem-based activities often provide important economic benefits. For example, thousands of birders travel to the Platte River in Nebraska each spring to witness the annual migration of Sandhill Cranes. The birders' total gross economic output has been estimated in the tens of millions of dollars. Trends in the demand for ecosystem-based recreation in the Missouri River basin continue to increase.

The values of many of these services historically have not been monetized and are not traded in economic markets. Changes in the benefits flowing from these services are thus not easily recognized. With the exception of select outdoor recreation activities, most ecosystem goods and services tend to be undervalued by decision makers and in resources management policies. But there is a growing recognition that the replacement costs of these services, assuming their replacement is even possible, would be very high.

Degradation of the natural Missouri River ecosystem is clear and is continuing. Large amounts of habitat have been transformed to enhance social benefits, and the ecosystem has experienced a substantial reduction in biological productivity as a result. Natural riverine processes, critical to providing ecosystem goods and services, have been greatly altered. The ecosystem has been simplified and its production of goods and services has been greatly compromised.

Degradation of the Missouri River ecosystem will continue unless some portion of the hydrologic and geomorphic processes that sustained the pre-regulation Missouri River and floodplain ecosystem are restored—including flow pulses that emulate the natural hydrograph, and cut-and-fill alluviation associated with river meandering. The ecosystem also faces the prospect of irreversible extinction of species.

STATE OF THE SCIENCE

There is a rich, extensive body of scientific research on the Missouri River ecosystem that can provide the foundation for future river management actions. For example, a 1997 technical report from the U.S. Geological Survey listed 2,232 studies of the Missouri River ecosystem. These scientific studies date back to Lewis and Clark's epic 1804–1806 expedition. Since then, many individuals and government agencies have studied the basin's natural vegetation, fishes, water quality, and impacts of dams. This research has greatly improved scientific understanding of the river's ecosystem and how it has changed. These studies have provided careful documentation of the ecological changes described in this report.

Research on the Missouri River ecosystem provides a sound scientific understanding of ecological structure and the controlling river processes, and how they were impacted by human actions during the twentieth century. Although knowledge of the ecological intricacies within a system as large as the Missouri River ecosystem will always be limited by scientific uncertainties, the system's broad ecological parameters and patterns are currently well understood.

Nonetheless, existing studies are only a starting point for future management choices because this extensive body of research has not been adequately synthesized. Further, the studies have tended to focus on specific species or portions of the river. Only a few studies of Missouri River ecology view the river as a single system from headwater to mouth, or as a single system that considers biological and physical linkages.

The lack of synthesis and utilization of these scientific data may be as much a function of institutional and political barriers as it is of the limitations of the scientific information itself. Neither discrete scientific disciplines nor mission agencies have been provided with sufficient incentives to conduct this synthesis and integration. Without this fundamental information, cast within a system-wide perspective encompassing the entire Missouri River ecosystem, truly comprehensive assessments of the ecological state of the Missouri River are not possible.

The most significant scientific unknowns in the Missouri River ecosystem are how the ecosystem will respond to management actions designed to improve ecological conditions. In addition to improving ecological conditions, such actions can also help supplement existing scientific knowledge, especially in understanding how select ecological variables respond to different environmental conditions. Management actions, cast as carefully circumscribed and monitored experiments, are necessary in order to advance our understanding of how regulated rivers respond to changes. It is important that ecosystem monitoring programs be designed specifically to produce results that serve as input into river ecosystem recovery programs.

The emerging paradigm of adaptive management provides a useful conceptual basis for framing such management actions. The concept has been and is currently being used to guide ecosystem restoration efforts in the Colorado River, the Columbia River, and the Florida Everglades. Adaptive management is also being initiated by Missouri River management agencies. The U.S. Army Corps of Engineers, for example, in its August 2001 revised draft environmental impact statement for the Missouri River Master Water Control Manual, acknowledges the importance of adaptive management.

This committee was requested to comment on "policies and institutional arrangements . . . that could promote an adaptive management approach to Missouri River and floodplain ecosystem management." Adaptive management recognizes that scientific uncertainties and unforeseen environmental changes are inevitable. It thus seeks to design organizations and policies that can adapt to and benefit from those changes. Adaptive management is not merely an elaborate "trial and error" approach. Rather, it emphasizes the use of carefully designed and monitored experiments, based on input from scientists, managers, and citizens, as opportunities to maintain or restore ecological resilience and to learn more about ecosystems. These actions are monitored for scientific findings to help improve understanding of how policy decisions affect ecosystems. Findings from ecosystem monitoring are then to be used to appropriately adjust management policies. Adaptive management requires that clear goals and desired outcomes be established so that progress toward desired future conditions can be assured.

Although adaptive management is a powerful approach that holds great potential, it should not be viewed as a panacea for Missouri River basin management and ecosystem improvements. The committee is keenly aware that the practice of adaptive management is "a work in progress" and that there is inadequate experience with successful or unsuccessful experiments to comprehensively evaluate the underlying theory. Adaptive management is not necessarily easy to implement and execute and, like the Missouri River basin itself, presents many complexities. In those ecosystems where it has been implemented, it has proven useful in many ways. However, endangered species are still listed, stakeholders still disagree with one another, and key management agencies are constrained by resources, legal mandates, and political realities. Nonetheless, there can be little disagreement that a new management paradigm is needed if further declines in the Missouri River ecosystem are to be halted and reversed. Adaptive management represents a framework for promoting stakeholder discussion and for strengthening the links between the Missouri River ecosystem and the region's economies and societies. Just as adaptive management encourages experiments, implementation of adaptive management will in itself represent an experiment. But no other alternative restoration strategy holds the promise that adaptive management does, and federal, state, and local governments, as well as several other National Research Council committees, have embraced the concept as an important instrument to promote biodiversity conservation and restoration.

The U.S. Army Corps of Engineers, in cooperation with the U.S. Fish and Wildlife Service and several state agencies, has completed and is implementing several habitat preservation and restoration projects along the Missouri River. These projects represent useful steps toward recovering the Missouri River ecosystem. However, they are limited in scope, are insufficiently coordinated among agencies and among various reaches of the river, receive inconsistent funding, and lack adequate support for monitoring. These programs also are not framed within an overarching plan for recovering key elements of the Missouri River's pre-regulation hydrologic and geological processes. The sum of these efforts is insufficient to noticeably recover ecological communities and fundamental physical processes in the Missouri River ecosystem. To substantially improve the ecosystem, a more systematic and better-coordinated approach that considers ecological conditions on par with other management goals in the entire Missouri River system will be required.

MISSOURI RIVER NAVIGATION AND BANK STABILIZATION

No Missouri River management issue has polarized the river's stakeholders as much as the debate over how the provision of flows and channel depths for navigation has affected the Corps' ability and willingness to meet ecosystem needs. Improved navigation was a major feature of the mid-twentieth century vision of the 1944 Pick–Sloan Plan, as navigation's future economic benefits were assumed to be substantial. However, the 1950 projections for commercial waterway traffic were overly optimistic; commercial towboat traffic on the Missouri River peaked in 1977 (below projected levels) and has fallen slowly and steadily since then.

Missouri River navigation, conducted on the river's 735-mile channelized stretch between Sioux City, Iowa and St. Louis, Missouri, is controversial for both economic and environmental reasons. The current dam and reservoir operation schedules reduce the river's natural hydrologic variability in order to provide a steady and reliable 9-foot deep navigation channel. Such operations run counter to established river science, in which a large degree of natural hydrological variability is essential to biological productivity and species richness of large floodplain rivers. Resolution of the differences between managing flows for navigation or for more natural hydrology is constrained by the fact that the benefits of navigation are expressed in dollars, while the benefits of ecosystem improvements from operational changes have yet to be monetized.

The ultimate decision regarding the proper balance between these uses is a public policy issue and, as such, is beyond this committee's charge. Nevertheless, this issue is so crucial to the river's future that this committee could not ignore it. Differences of opinion may be artificially magnified by considering Missouri River navigation as an "all or nothing" type issue. Cooperative dialogue might be easier if incremental changes in navigation and river management are considered.

Because net national navigation benefits are relatively small in total, and because waterway traffic volumes decrease moving upstream, an incremental analysis of the economics of retaining segments of the navigable waterway would be useful. Relaxing the responsibility to maintain navigation flows would make it demonstrably easier to introduce flows for improving river ecology in that segment. As an example, if the segment from Sioux City, Iowa downstream to Omaha, Nebraska proved to be uneconomic when comparing its incremental benefits with its incremental costs—factoring in the values of all potential ecosystem goods and services—then that segment would be a candidate for enhancing river ecology through operational changes. Ecological enhancement, however, would not necessarily proceed rapidly. The banks along the river's navigable channel are stabilized and contain communities and other important infrastructure in many areas. If it is decided to enact management actions to improve the state of the ecosystem, and if those management actions are to be effective, some degree of Missouri River meandering must be restored. Allowing the Missouri River to meander would require a significantly wider public corridor in some portions of the channel than currently exists. This would require close coordination with those who live and work along the river. In some cases, significant improvements in river ecology may require relocations.

In proceeding segment by segment, the analysis should discover the point at which it is beneficial to retain navigation to the mouth of the river. The case for retaining some navigation might be stronger if navigation were discontinued or less fully supported in those segments where it is economically inefficient. Congress should give the Corps of Engineers authority to provide navigation services on an incremental basis along the channelized portion of the Missouri River, to be exercised on the basis of analysis and stakeholder input.

POLICIES, INSTITUTIONS, AND ADAPTIVE MANAGEMENT

The Corps of Engineers constructed and operates six of the seven mainstem dams on the Missouri River; the U.S. Bureau of Reclamation operates the seventh, Canyon Ferry Dam, east of Helena, Montana. When the Corps of Engineers constructed the Missouri River mainstem dams in the 1950s and 1960s after passage of the Pick–Sloan Plan, the goals for dam and reservoir operations were to reduce flood damages, enhance navigation, generate hydroelectric power, and store water for irrigation. But changes in social preferences have resulted in a new mix of uses and stakeholders on the Missouri River today. Many of these new uses revolve around recreational and environmental considerations, such as boating and sport fishing. Some Missouri River stakeholders, such as environmental and recreational groups, call for revised operations and a redistribution of the river's benefits. Other stakeholders, such as the navigation industry, the hydropower industry, and floodplain farmers generally prefer the status quo.

Scientific knowledge, economies, and social preferences have clearly changed across the Missouri River basin since the mainstem dams were planned and constructed. However, the institutional and policymaking framework for Missouri River management has not changed accordingly. The decision-making context for the Missouri and its tributaries is characterized by prolonged disputes, disaffected stakeholders, and degrading ecological conditions. Barriers to resolving this policy gridlock on the Missouri River include a lack of clearly stated, consensus-based, measurable management objectives, powerful stakeholders' expectations of a steady delivery of entitlements, and sharply differing opinions and perspectives among some Missouri River basin states.

Current management protocols for operating the Missouri River system represent an accretion of federal laws, congressional committee language, appropriations instructions, and organizational interpretations that have been enacted or developed over the past century. This guidance has generally not been updated to reflect changing economic and social conditions, new needs in the basin or the nation, or large improvements in scientific knowledge. The Corps of Engineers and some basin stakeholders view the collective statutes, committee reports, and agency interpretations as barriers to prospective management changes that would seek to balance ecological values and services with current realities and values of navigation, recreation, and sound floodplain management. Although this committee believes the Corps of Engineers may have greater legal authority to manage the Missouri River system than it has exercised, the Corps' ability to do so has been constrained by sharp differences of opinion among stakeholders. If the condition of the Missouri River ecosystem is to improve, agencies responsible for adaptive management must have clear lines of authority and the necessary resources to work toward this goal.

The Corps of Engineers has always set the water release schedules for the Missouri River mainstem dams. Guidance for mainstem dam water release priorities is established in the Corps' Missouri River Main Stem Reservoir System Reservoir Regulation Manual, also known as the "Master Manual." Decisions regarding water release schedules from the Missouri River mainstem reservoirs ultimately determine the distribution of the river's benefits. As mentioned, these decisions have become increasingly controversial and pose challenges to the Corps.

In the late 1980s, the Corps of Engineers began a revision to its 1979 Master Manual that today—fourteen years later—is not yet complete because of competing demands for the river's resources and sometimes strong differences of opinion. In working toward this revision, the Corps has consulted with numerous stakeholders and the public at large across the Missouri basin, including environmental groups, the navigation industry, farmers, and other floodplain residents and communities. Any agency would be challenged to find a solution amenable to all users in the current context of Missouri River management, and a consensus on how the dams and reservoirs are to be operated has remained elusive. A moratorium on further revision of the Master Manual should thus be implemented until such revisions reflect a collaborative, science-based approach based upon adaptive management to improve the condition of the Missouri River ecosystem.

Adaptive management should be adopted as an ecosystem management paradigm and decision-making framework for modifying water resources and reservoir management for the Missouri River ecosystem. As part of this management strategy, the goal of improving ecological conditions should be considered on par with other management goals. Specific Missouri River adaptive management experiments and activities—involving a broad spectrum of river system stakeholders in a collaborative process to establish goals and guidelines for such experiments—should be implemented as soon as possible. Adaptive management actions for improving ecological conditions should be examined and conducted within a systems framework that considers the entire Missouri River ecosystem from headwaters to mouth, as well as the effects of tributary streams on the mainstem.

Determining specific goals and objectives for Missouri River management that society desires will require the participation of a wide spectrum of groups with stakes in Missouri River management. Missouri River mainstem reservoir operations objectives and means, including adaptive management actions, should be set by a formal multiple-stakeholder group that includes, but is not necessarily limited to, the U.S. Army Corps of Engineers, the U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. National Park Service, Indian tribes, the Missouri River basin states, floodplain farmers, navigation groups, municipalities, and environmental and recreational groups. The stakeholder group should review other adaptive management efforts to learn about successes, failures, and potential management actions that could be usefully implemented on the Missouri. To help resolve scientific uncertainties and to assure progress in considering some level of ecosystem recovery, a scientific peer-review process that includes an independent, interdisciplinary scientific panel should provide solicited input to the stakeholder group.

Support of the U.S. Congress is ultimately needed to help establish acceptable goals for the use and management of the Missouri River system. Congress must also identify the necessary authorities to do so. The stakeholder group should help frame Missouri River management decisions. But if the trends of ecosystem decline are to be halted and reversed, that stakeholder group must define ecosystem improvements as one of its key goals. Federal legislation mandating ecosystem protection and enhancement is one means to help stakeholders focus on Missouri River ecology. Sustained stakeholder participation in a system the size of the Missouri River ecosystem, and in which there are sharp differences of opinion over appropriate management goals, will require sustained commitments of time and resources. Some of the participants may possess inadequate resources and will require assistance to ensure their participation. Successful implementation of adaptive management will also require administrative and facilitation resources.

Congress should provide the necessary legislative authorities and the fiscal resources to implement and sustain an adaptive management approach to Missouri River management. Resources should include administrative and facilitation services for a multiple-stakeholder group to develop consensus positions on river management objectives and reservoir operations policies. To ensure support of the adaptive management program and management actions that balance contemporary social, economic, and environmental needs in the Missouri basin, Congress should enact a federal Missouri River Protection and Recovery Act designed to improve ecological conditions in the Missouri River ecosystem. This act should include a requirement for periodic, independent review of progress toward implementing adaptive management in the Missouri River ecosystem.

1

Introduction

Rivers, watersheds and aquatic ecosystems are the biological engines of the planet.

World Commission on Dams, 2000

The Missouri River basin (Figure 1.1) extends over 530,000 square miles and covers approximately a sixth of the continental United States. The one-hundredth meridian, the boundary between the arid western states and the more humid states in the eastern United States, crosses the middle of the basin. The Missouri River's source streams are in the Bitterroot Mountains of northwestern Wyoming and southwestern Montana. The Missouri River begins at Three Forks, Montana, where the Gallatin, Jefferson, and Madison rivers merge on a low, alluvial plain. From there, the river flows to the east and southeast to its confluence with the Mississippi River just above St. Louis. Near the end of the nineteenth century, the Missouri River's length was measured at 2,546 miles (MRC, 1895). Large, looping meanders of the main channel, some of which were nearly circular and that measured tens of miles in circumference, were then prominent features of the river. Much of the river has since been dammed, straightened, and channelized, and these large meanders have been virtually eliminated. As a result, the Missouri River's length today is 2,341 miles—a shortening of roughly 200 miles (USACE, 2001).

FIGURE 1.1 The Missouri River Basin.
SOURCE: USACE, undated.

Between 1804 and 1806, Meriwether Lewis and William Clark led the first recorded upstream expedition from the river's mouth at St. Louis to the Three Forks of the Missouri, and eventually reached the Pacific coast via the Columbia River. The Missouri River subsequently became a corridor for exploration, settlement, and commerce in the nineteenth and early twentieth centuries, as navigation extended upstream from St. Louis to Fort Benton, Montana. Social values and goals in the Missouri River basin in this period reflected national trends and the preferences of basin inhabitants. Statehood, federalism, and regional demands to develop and control the river produced a physical and institutional setting that generated demands from a wide range of interests.

Over time, demands for the benefits from the Missouri's control and management resulted in significant physical and hydrologic modifications to the river. These modifications led to substantial changes in the river and floodplain ecosystem. Numerous reservoirs are scattered across the basin, with seven large dams and reservoirs located on the river's mainstem. Six of these dams were constructed pursuant to a 1944 agreement between the U.S. Army Corps of Engineers and the Department of the Interior's Bureau of Reclamation. The agreement, ratified by the U.S. Congress, is known as the Pick—Sloan Plan and is the effective existing management regime for the Missouri River. The Pick—Sloan Plan represented a merger of Missouri River basin development plans that were formulated independently in the early 1940s by the Corps of Engineers (the Corps' "Pick Plan" was headed by Colonel Lewis A. Pick) and the Bureau of Reclamation (the Bureau's "Sloan Plan" was headed by Regional Director William G. Sloan). The separate plans were coordinated in Senate Document 247 (S.D. 247), which was part of the Flood Control Act passed by Congress on December 22, 1944. The final paragraph of S.D. 247 states that the plan "will secure the maximum benefits for flood control, irrigation, navigation, power, domestic, industrial and sanitary water supply, wildlife, and recreation."

The first public mainstem dam on the Missouri River pre-dated Pick—Sloan. The Fort Peck Dam was built in Montana in the 1930s as a Public Works Progress Administration project promoted by President Franklin D. Roosevelt. The five mainstem dams downstream of Fort Peck and dozens of tributary dams were constructed as part of Pick—Sloan. Missouri River mainstem reservoirs behind Fort Peck Dam in Montana (Fort Peck Lake), Garrison Dam in North Dakota (Lake Sakakawea), and Oahe Dam in South Dakota (Lake Oahe) are three of the nation's five largest human-made lakes (only Lake Mead and Lake Powell, both on the Colorado River, are larger). Although the river and its tributaries are extensively controlled by dams, channel modifications, and bank stabilization projects, the Missouri River is still subject to flooding, especially on the lower river. Like most major U.S. water projects, the Missouri River dams were authorized and built prior to the passage of modern environmental statutes such as the National Environmental Policy Act and the Endangered Species Act (but not the Fish and Wildlife Coordination Act of 1934, which pre-dates most of the dams).

The Corps of Engineers constructed and operates six of the Missouri's seven mainstem dams (the Bureau of Reclamation constructed and operates Canyon Ferry dam, the comparatively small mainstem dam farthest upstream on the Missouri River). Operations of these six dams are guided by the Corps' 1979 Missouri River Main Stem Reservoir System Reservoir Regulation Manual, usually referred to as the "Master Manual." A severe drought across the basin in the late 1980s and early 1990s focused national attention on the tensions and conflicts among management objectives and competing beneficiaries. During this drought, upper basin reservoirs were drawn down (reducing benefits for recreation and tourism), and lower basin states experienced disruptions to navigation and water supplies.

The pronounced drought of 1988—1992 affected most parts of the Missouri River basin. Negative impacts on reservoir-based recreation (upstream), on navigation (downstream), and on threatened and endangered species were so severe that in 1989, Congress directed the Corps to review the Master Manual. That review was conducted according to guidelines in the National Environmental Policy Act (NEPA), which required the Corps to conduct an environmental impact statement regarding changes in dam operations. As early as August 1994, the U.S. Fish and Wildlife Service (USFWS) issued jeopardy opinions (which state that a proposed action will jeopardize the existence of a threatened or endangered species) regarding operation of the Missouri River dams and the threat to federally listed species (the Fish and Wildlife Service opinions were issued as part of the environmental impact study process). This followed the Corps' issuance of the Master Manual Draft Environmental Impact Statement, which recommended changes in the management of the dams and reservoirs. The Corps conducted public hearings on this draft document. These hearings revealed controversies and passionately-held beliefs surrounding the river's many users. A consensus emerged that recognized the need for improved ecological monitoring and scientific knowledge to improve river management. Nevertheless, the National Environmental Policy Act environmental impact statement (EIS) process—initiated when the Corps began revisions to its Master Manual in 1989—and a final revision of the Corps' Master Manual for operation of the Missouri River system had not been completed in early 2002, nearly 14 years after the Master Manual revision process began. Congress, the Missouri River basin states, and the basin's water users and interest groups disagree upon the appropriate water release schedule (including timing, locations, and quantities of water) for the Missouri River's mainstem reservoirs.

In 1999, with sponsorship of the U.S. Environmental Protection Agency (EPA) and the Corps of Engineers, the Water Science and Technology Board of the National Research Council (NRC) formed a committee of experts to help provide a better scientific basis for river management decisions in the Missouri River basin. This study complements similar studies recently conducted by the NRC in the Columbia River basin, the Colorado River basin, and the Florida Everglades and the Upper Mississippi River. It also recognizes a growing public interest in redressing modifications made to large river ecosystems. This committee was given the following charge:

> This committee will provide a general characterization of the historical and current status, and important ecological trends, of the Missouri River and floodplain ecosystem. The committee will provide a review of the available scientific information on the Missouri River and floodplain ecosystem, and will identify and prioritize scientific information needs for improved Missouri River management. The committee will also recommend policies and institutional arrangements that could improve scientific knowledge of the Missouri River and floodplain ecosystem, and those that could promote adaptive management of the Missouri River and floodplain ecosystem.
>
> The committee's task is thus divided into three objectives:
>
> 1) Characterize the historical and current ecological status of the Missouri River and floodplain ecosystem. This overview will identify key ecological conditions, changes, and processes, endangered and threatened species, trends and relevant time scales, and gaps in and the limits of that knowledge.
>
> 2) Identify and describe the general state of existing scientific information on the Missouri River and floodplain ecosystem. Identify and prioritize the key scientific questions to be addressed and the key scientific information needed for improved Missouri River management.
>
> 3) Recommend policies and institutional arrangements for improving Missouri River and floodplain ecosystem monitoring and research, and those that could promote an adaptive management approach to Missouri River and floodplain ecosystem management.

This committee began its two-year study late in 1999. Five meetings were held along the river: Bismarck, North Dakota; Columbia, Missouri; Great Falls, Montana; Omaha, Nebraska; and Pierre, South Dakota (a sixth meeting was held at the National Academies' Beckman Center in Irvine, California, in February 2001). The committee spoke with federal and state scientists and engineers, representatives from Indian tribes, experts on Missouri River institutions and policies, groups interested in Missouri River ecology and river management, the commercial navigation industry, and many citizens.

This report focuses on the Missouri River ecosystem. However, an understanding of the larger context of water resources development is helpful in explaining some of the patterns reflected across the Missouri basin. Namely, changing values and water management policies in the United States are part of a larger global shift in which assumptions about the benefits of dams and the ability to appropriately distribute those benefits are being rethought.

ECOLOGICAL CONDITIONS AND TRENDS IN U.S. RIVERS

The rivers of the United States underwent considerable hydrologic and ecological changes during the twentieth century. The most obvious of these changes was the inundation of extensive stretches of these rivers behind dams. The twentieth century saw the Corps of Engineers and the Bureau of Reclamation, along with local, state, and private entities, construct hundreds of dams and greatly increase water storage. For example, in a given year, 60 percent of the United States' entire river flow can be stored behind dams (Hirsch et al., 1990). Dams in the Missouri River basin are estimated to have the capacity to hold roughly 106 million acre-feet of water, with the six Corps of Engineers Missouri mainstem reservoirs having a combined capacity of roughly 73.4 million acre-feet, making it North America's largest reservoir system (USACE, 2001a). The waters stored by these reservoirs are intended to serve multiple purposes, including irrigation, recreation, and controlled releases for navigation enhancement. The reservoirs are also operated so that some amount of flood-control storage is available, an amount that fluctuates through the year in response to snowpack and precipitation conditions in the basin.

Major hydrologic changes in some sections along the Missouri River attended the closures of the mainstem Missouri dams: Fort Randall in 1952, Garrison in 1953, Gavins Point in 1955, Oahe Dam in 1958, and Big Bend Dam in 1963. When they were constructed, the Missouri River mainstem dams were intended to help control river flows and to reduce streamflow variability. Today, however, there is a better understanding of and appreciation for the ecological values and services supported by streamflow variability (Box 1.1 describes the values of ecosystem goods and services). Decreases in riverine wetlands and other riparian (streamside) habitats in U.S. river systems have resulted from population growth and economic development, as well as from structural alterations (e.g., straightening of channels, bank stabilization, and construction of wing dams) designed to constrict flows to a main channel. A variety of indicators might be used to measure changes in these ecosystems. To use one example, a National Research Council committee estimated that total wetland acreage in the contiguous United States decreased by approximately 117 million acres—half the original total—by the mid-1980s (NRC, 1995). Another study found that two-thirds of the pre-European settlement areas of riparian vegetation in the United States have been replaced by other land uses (Moberly and Sheets, 1993). Regardless of the measure that might be chosen, U.S. riparian ecosystems have been greatly altered during the past century.

Human impacts on U.S. Rivers have reduced populations of many aquatic species, including some extinctions. In the Columbia River basin, Pacific salmon have disappeared from about 40 percent of their historical breeding ranges over the past century (NRC, 1996). In the Upper Mississippi–Illinois River system, the number of mussel species has declined by 23 percent to 44 percent since European settlement in the basin in the nineteenth century (USGS, 1999). Only four of eight endemic fishes remain in the Grand Canyon reach of the Colorado River, and some of these are threatened or endangered (Minckley, 1991).

Box 1.1
Ecosystem Goods and Services

Although knowledge of the importance of ecosystems to societies and economies dates back centuries, the discussion of nature's importance in terms of goods and services is a relatively recent phenomenon. Because many functions provided by ecosystems are not monetized and are not traded in markets, values are often under-appreciated by the public and by decision makers (cf. Daily, 1997). For example, clean air and clean water provided by ecosystems are fundamental to healthy societies and economies, but price tags are generally not affixed to air and freshwater systems. They thus may be treated as having no monetary value in market-based decisions. But if rational natural resources decisions are to be made, it is important to understand how ecosystems provide value to societies and the magnitude of those values. Ecosystem goods and services include fish protein, fish-based recreation, biomass fuels, wild game, timber, clean air and water, medicines, species richness, maintenance of soil fertility, and natural recharge of groundwater. Consistent with the fact that ecosystem goods and services are generally not priced, are not traded in markets, and are not owned, they tend to become needlessly scarce. To remedy this, conservation programs that protect fish and wildlife are enacted, parks and natural reserves are created, the use of the biosphere as a sink for wastes is regulated, and programs aimed at restoring natural habitat are mandated.

A variety of approaches are in use to correct for the unowned and unpriced nature of many ecosystem goods and services. Tradable rights or quotas have been introduced for certain pollutants and in some fisheries. Charges are levied by governments to prevent the overuse of certain goods and services. Several methods are used to place simulated market values on goods and services that would otherwise be unpriced in policy making or in court decisions.

Engineered changes in the nation's rivers have enhanced competition, predation, and other detrimental interactions between native and non-native species (Minckley and Deacon, 1991), which has contributed to the demise of native species. Missouri River reservoirs and river segments presently contain populations of exotic fishes, including cisco, several salmon and trout species, and several Asian carp species (Hesse et al., 1989). Some of these species have contributed to the development of economically important recreational fisheries. On the Upper Mississippi River, scientists reported increased abundance of species such as bluegill and largemouth bass, which colonized habitats with slow-moving (lentic) water, after the river's navigation dams were constructed (Fremling and Claflin, 1984).

SHIFTING VALUES AND PUBLIC PREFERENCES

Since the 1970s, large, regional water projects no longer enjoy the widespread political support they once did. The economic rationale for these projects has eroded, and there is today more concern over these projects' environmental and social costs. As a result, the arid and semiarid western United States is shifting from the reclamation era—characterized by the construction of large, federally subsidized regional water projects—to an era of reallocation, conservation, and ecosystem restoration. The Bureau of Reclamation today focuses on management and maintenance of existing projects and on ecological improvements in degraded stream systems. Similarly, the Corps of Engineers is faced with the challenge of carrying out engineering and construction activities while balancing competing social, environmental, and economic demands in highly developed and highly controlled river systems. The Corps' traditional roles have been expanded by Congress to include environmental restoration and programs that address environmental problems associated with existing projects. For example, the Corps plays a central role in the multi-billion dollar Florida Everglades restoration project.

The value of dams today is questioned by segments of society that value environmental preservation and enjoyment. Some smaller U.S. dams have been breached or removed (e.g., Edwards Dam on the Kennebec River in Maine was breached in 1999), and others are scheduled to be removed (e.g., Elwha Dam in the state of Washington). In addition, the possible removal or decommissioning of some large federal dams (e.g., four dams on the lower Snake River and Hetch Hetchy Dam in Yosemite National Park) has been discussed (ASCE, 1997; Gleick, 2000). During the 1980s and 1990s, Congress passed specific legislation aimed at protecting and/or restoring aquatic ecosystems in the Columbia River basin, the Florida Everglades, the Grand Canyon, and the San Francisco Bay Delta. The need to consider the conditions under which dams and hydroelectric power facilities should be retired has also drawn attention from professional engineering groups (ASCE, 1997).

Changing views toward large dams are reflected in the recent report of the World Commission on Dams (WCD, 2000). In 1997, the World Bank and the International Union for the Conservation of Nature and Natural Resources (The World Conservation Union) assembled a group to discuss the highly controversial issues associated with dams. These parties agreed to a proposal to work together to establish a World Commission on Dams (WCD), which in 1998 began a comprehensive global and independent review of the performance and impacts of large dams. The commission's final report was issued in 2000. Although care must be taken in applying findings from the commission's global review of dams to the Missouri River, many of the commission's findings regarding environment, indigenous people, equity, and sustainability are applicable to the Missouri River basin and to the United States. This committee reviewed the commission's report with interest and, where its findings are relevant, refers to the commission's report (WCD, 2000).

ADAPTIVE MANAGEMENT

To properly balance social, economic, and environmental considerations in large river ecosystems, organizations and management policies must be able to respond to and take advantage of changing environmental, social, and economic conditions, as well as address extreme events. The concept of adaptive management promotes the notion that management policies should be flexible and should incorporate new information as it becomes available. New management actions should build upon the results of previous experiments in an iterative process. It stresses the continuous use of scientific information and monitoring to helporganizations and policies change appropriately in order to achieve specific environmental and social objectives. Adaptive management promotes collaborative and consensus-based decision-making. Adaptive management promotes "thinking outside the box" and promotes stakeholder discussions about the desired state of the ecosystem. Responsive organizations and policies that can adjust decisions on dam operations are needed to meet changing scientific and social goals: "Dams and the context in which they operate are not seen as static over time. . . . . Management and operation practices must adapt continuously to changing circumstances over the project's life and must address outstanding social issues" (WCD, 2000).

Adaptive management requires an organizational and political framework for its full and proper implementation. To be successful, it should be implemented by organizations with sufficient legal authority and political legitimacy to appropriately adjust management policies. Scientific investigations will never eliminate all economic, engineering, environmental, and social uncertainties in large ecosystems like the Missouri River basin. Policy decisions must account for these uncertainties. Organizations responsible for promoting adaptive management must have the legal authority and the stakeholder support necessary to make and enforce recommended changes in current management regimes.

Adaptive management also promotes the advancement of scientific knowledge through carefully designed experiments and monitoring systems. Water resources managers and scientists across the United States are conducting numerous experiments, at a range of spatial and temporal scales, with water releases and diversions to benefit select species and ecosystems. Perhaps the most prominent experiments in river and dam management are controlled releases of high flows from reservoirs. The most famous controlled release in United States water management was a controlled flood from Glen Canyon Dam in March 1996. The controlled flood in the Grand Canyon aimed to restore beaches that had been damaged by decades of low hydrologic variability. The notion of operating a dam to purposely create a large flood represented a milestone in U.S. water management. Former Secretary of the Interior Bruce Babbitt described the event and the process leading up to it: "There was simply no precedent on the Colorado River—or as far as we know anywhere in the history of civilization—for what Interior was proposing to do" (Babbitt, 1999). Beyond reservoir releases, possible adaptive management actions include changing the length of navigation seasons, changing patterns of irrigation water withdrawals, changing elevations of navigation pools, and constructing notches in flood-control levees.

This committee studied carefully the history of efforts to create coordinated management schemes for the Missouri River basin through federal river authorities modeled on the Tennessee Valley Authority (TVA), through interstate compacts, and through an entity composed of federal, state, and tribal representatives. In general, the proposed organizations lacked the necessary political support to achieve agreement on implementation and have thereby been unable to resolve most intra-basin conflicts. The lack of such a management authority in the Missouri River basin has created a management vacuum that has been filled by the Corps and increasingly by the courts (Thorson, 1994). If adaptive management is chosen as a paradigm by which to coordinate Missouri River management organizations and policies, it must be considered and implemented in the context of these current and historical organizational efforts. It would require Congress, federal and state agencies, Indian tribes, and other public and private stakeholders to forge an agreement placing adaptive management at the center of a process for reaching compromises on the full array of river management issues.

This committee addressed its charge against a backdrop of over a century of actions devoted to developing and managing the Missouri River for economic and social ends. Before evaluating contemporary Missouri River management issues, a review of the historical development of the Missouri River and its floodplain is appropriate.

2

Missouri River History, Management, and Legal Setting

Much of western history is a series of lessons in consequences.

Wallace Stegner, 1962

The Missouri River links together a large and varied region that stretches across the continental United States. The mountainous terrain in the basin's western reaches, the aridity in the basin's western and middle sections, and the more humid climate in the eastern part of the basin have shaped the basin's landscape, ecology, and patterns of settlement. Humans have altered the Missouri River and surrounding lands to address both the challenges of limited water supplies during drought and high flows during floods. In some cases, these alterations have led to conflicts among the Missouri basin's upstream and downstream states. They have also resulted in significant modifications of the basin's natural environment in general and of the Missouri River and floodplain ecosystem in particular.

PHYSICAL GEOGRAPHY

During the last ice age, glaciers that extended southward from Canada into the northern United States defined the Missouri River basin's northeastern boundary. Glacial lobes directed the Missouri River drainage toward the Mississippi River. Before the glaciers, much of the upper basin (northward of the Bad River's present confluence with the Missouri at Pierre, South Dakota) drained northeastward into Hudson Bay. On the basin's southern margins, a low ridge and the Ouachita Mountains today separate the Missouri River basin from the Arkansas River basin.

The basin's northern landscapes include level to gently rolling continental glacial till plains and hills. The region between the Missouri River (on the north) and the South Dakota–

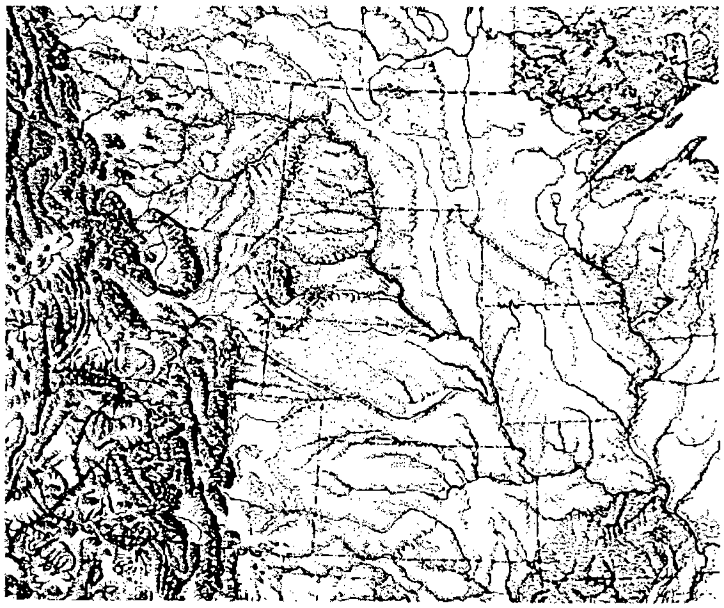

FIGURE 2.1 Missouri River basin landscape.

Nebraska border (on the south) is arid and has eroded to form deep valleys. From there to the basin's southern boundary lie the Great Plains, with their characteristic widely spaced streams and broad, flat valleys. In the basin's eastern third, the plains give way to upland plateaus and gently rolling till plains. Annual rainfall varies from 8 inches in the foothills of the Rockies to over 40 inches in parts of Missouri and Iowa. Much of the basin is characterized by the cold winters and hot summers associated with a continental climate (drier in the basin's western portions, more humid in the east). Throughout the basin, most rain falls during the spring and summer. The basin's western rivers, such as the Marias and the Yellowstone, gain a large portion of their flow from spring snowmelt.

Limited moisture in the basin's western sections is associated with prairie grasses that stretch from the Rocky Mountain foothills eastward to near the one-hundredth meridian. Before nineteenth century Anglo settlement, trees were typically found only along riparian areas. In the eastern basin, the vegetation shifts to mixed oak and hickory forest interspersed with open grass plains. In the basin's middle section in central Nebraska and central South Dakota, crops can be grown without extensive irrigation during wetter years. West of the one-hundredth meridian, limited and sporadic moisture generally limits agricultural production to wheat and small grain crops. Farther west, precipitation decreases and crops give way to livestock grazing and dryland wheat farming.

The Missouri River flows from Three Forks, Montana to its confluence with the Mississippi River in St. Charles County, Missouri, just north of St. Louis. Along its winding course to the Mississippi River, the Missouri River flows through or borders seven states, with the river basin encompassing ten states. The westernmost tributaries of the Missouri River begin at elevations near 11,000 feet. Flowing downstream and eastward through Montana, the Missouri River is joined on the north by the Milk River, the Missouri's only major tributary that extends into Canada. Farther downstream, the Yellowstone River joins the Missouri near the Montana–North Dakota border. It is then joined by the Little Missouri, Knife, Cheyenne, Bad, Grand, Niobrara, Platte, and Kansas rivers and several smaller tributaries, all of which enter from the Missouri's right bank. Between the Milk River in Montana and the James River (which enters the Missouri just northwest of Sioux City, Iowa, on the southern South Dakota boundary), no major tributaries join the Missouri from the north (its left bank). Downstream from the Missouri River–James River confluence, the Vermillion, Big Sioux, Little Sioux, Chariton, Osage, and Gasconade rivers enter the Missouri from both the left and right banks. Where the Missouri joins the Mississippi just above St. Louis, the Missouri River has fallen to an elevation of slightly less than 400 feet.

HUMAN SETTLEMENT

Native Americans were the Missouri River basin's first known inhabitants. Spanish explorers, followed by British and French fur traders, were the first Europeans to enter the Missouri basin. The exploration and settlement of the Missouri basin represents a fascinating and well-documented chapter in the history of United States' westward expansion (DeVoto, 1947; Webb, 1931). The basin became part of the United States with the Louisiana Purchase in 1803. President Thomas Jefferson's interests in the basin's physical geography, ecology, and its Native American tribes led to Lewis and Clark's celebrated expedition. Between 1804 and 1806, Lewis and Clark's "Corps of Discovery" explored the river from its mouth to its headwaters and opened the Missouri basin to the exploration and settlement of a growing United States (Ambrose, 1996). In "the greatest wilderness trip ever recorded" (Botkin, 1995), the group's journey was remarkable not only for the distance covered and the dangers and hardships encountered and overcome, but also for its scientific discoveries.

Lewis and Clark's reports led subsequent explorers to see the region as a route to the West for trade with the Indians, and a region for possible mineral extraction. In the early nineteenth century, travelers within the basin relied on the river for transportation and on the benevolence of the natives for their survival. Navigation eventually reached Fort Benton, Montana, in the Rocky Mountain foothills, and carried a great deal of river traffic in the first half of the nineteenth century. But as the railroads expanded and reached the banks of the Missouri (St. Joseph, Missouri, 1859; Bismarck, North Dakota, 1872) and eventually crossed over it to move to the West (reaching Casper, Wyoming, in 1884), reliance on waterways began to decline. Railroads ultimately had a greater influence on the basin's settlement patterns, especially in its upper reaches, than did steamboats and river navigation.

The westward movement brought settlement and farming, as well as commercial hunting. The basin's settlement initially had only limited ecological impacts. But as these activities intensified, they began to change the lives of Native Americans and the ecology of the Great Plains. The Missouri basin's settlement was encouraged by public land policies such as the Homestead Act of 1862 and Desert Lands Act of 1877. However, settlement in the basin's upper, interior reaches was more ephemeral compared to other parts of the west, as droughts and harsh winters there caused many to leave the basin.

During the nineteenth century, the prevailing assumption was that land disposition policies would be sufficient to settle and sustain the West, including much of the Missouri River basin. But by the twentieth century, based in part on John Wesley Powell's surveys of the arid regions of the western United States (Powell, 1878), the federal government realized that more substantial government intervention would be necessary to encourage and sustain further settlement and economic development in the vast, harsh portions of the basin.

CHANGES IN THE MISSOURI RIVER AND FLOODPLAIN

Irrigated Agriculture

Throughout the latter half of the nineteenth century, settlement of the western United States placed increasingly larger demands on the region's limited water resources. This period saw an increase in private sector efforts to move water from rivers to nearby arable lands. For example, by 1850 the Mormons were irrigating over 16,000 acres in the area that would become the state of Utah (Worster, 1985). Within the Missouri basin, irrigation cooperatives appeared in Colorado as early as 1859 (Dunbar, 1983). Small diversion dams were constructed and ditches were dug to carry diverted waters to fields for irrigation. Larger dams were eventually used to create storage reservoirs to capture spring runoff for use in the hot and dry western summers. By the end of the nineteenth century, many basin farmers were collaborating to develop irrigation projects that they hoped would ensure the availability of water for increasing acreage in agriculture.

Settlement of the Missouri River basin's arid areas required states to adjust their water laws to unfamiliar climatic conditions. The doctrine of prior appropriation, which provides that the water rights of users who first put water to beneficial use are senior to water rights established later, or "first in time, first in right," was adopted in varying degrees in the Missouri River basin's arid regions. Scholars continue to debate whether prior appropriation originated in New England to allocate the rights to the flow of streams among mill owners, or whether it was an application of mining and irrigation customs developed in the west (Pisani, 1996). Whatever its origins, it seems clear that prior appropriation represented a conscious effort to develop an irrigation society in an area of variable rainfall.

The two most arid Upper Basin states, Montana and Wyoming, rejected the common law of riparian rights in favor of prior appropriation. States split by the one-hundredth meridian took a more circuitous route to prior appropriation. The Dakotas initially adopted the common law of riparian rights and subsequently followed dual appropriative-riparian systems until the 1950s and 1960s when riparian rights were extinguished. Kansas and Nebraska went through a similar transition (Wells Hutchins, 2 Water Rights in the Nineteen Western States 1- 14, 1974). The more humid states of Iowa, Minnesota and Missouri followed the common law of riparian rights and later supplemented them with permit systems.

Areas along the Missouri River have never benefited from irrigated agriculture to the extent that other areas in the west have. Irrigated agriculture was in its infancy in the western United States during the 1850s and 1860s, a period during which farmers had limited political influence. But drought in the late 1880s, combined with the efforts of irrigation advocates such as George Maxwell and William Smythe, created the political momentum for a federal reclamation policy to settle the west (Pisani, 1992). The Reclamation Act of 1902 established federal support of irrigation in the western United States as a national policy and created the Reclamation Service, later renamed the Bureau of Reclamation. Missouri River basin residents were quick to recognize the potential for securing resources water resources development; they were, however, less able to profit from the program than areas farther west that had established irrigation districts. As western historian Walter Prescott Webb observed, "The United States government, after the most extensive surveys has not selected a project on the High Plains. . . . by law the national government was compelled to put at least one project in each arid state except Texas, but it will be noticed that the projects in Colorado, Nebraska, and North and South Dakota are placed in the most western portions of those states" (Webb, 1931).

By 1904, irrigation projects were underway in the Missouri River basin at several locations. For example, by 1909, the Yellowstone River was being diverted in two locations. By the 1930s, most of the Missouri's tributaries had one or more dams, diversion structures, or pump stations to store water or to shift it from the rivers and streams to arable lands. By 1939, federal dams had been constructed on the Belle Fourche, Milk, North Platte, Platte, Sun, and Shoshone rivers and their tributaries. Construction also was underway on a 14-dam project that would move 260,000 acre-feet of water a year from the Colorado River basin to the Big Thompson River of the Missouri River basin (Tyler, 1992). One pumped irrigation project was built along the Missouri River near its junction with the Yellowstone River. In these projects, irrigated crops such as sugar beets, beans, flax, and grains replaced dryland agricultural crops.

Navigation

As early as 1824, Congress appropriated funds to the U.S. Army Corps of Engineers to remove large tree snags and other obstacles in the Missouri River channel. Government snag boats and river-based work crews continued their efforts to improve navigability through the late 1870s. However, the volume of upper Missouri River traffic began to decline in mid-century, and by the late 1880s, river traffic essentially ended north of Sioux City, Iowa. At about the same time, the Corps began stabilizing riverbanks in populated areas to reduce losses to riverfront property.

In 1910, Congress, under pressure from farming and barge interests, authorized the development of a six-foot-deep navigation channel on the Missouri River from Kansas City to St. Louis. The project stalled, however, when Congress, faced with World War I, did not appropriate adequate funds for the project. By 1915, all activities had essentially stopped. In 1927, the project was resumed when Congress authorized extension of the six-foot-deep channel to Sioux City, Iowa, and authorized a feasibility study of a nine-foot-deep channel from Kansas City to St. Louis. With funding secured, the Corps launched a program combining bank stabilization with dike construction and strategic dredging designed to narrow the river and eliminate meandering. The dike fields soon filled with sediment, restricting the river to a relatively narrow channel. Wide bends were eliminated, the channel was narrowed, and the river's velocity increased. The result was a self-scouring channel that reduced the amount of dredging required. The Corps' focus on the lower basin ultimately linked navigation-enhancement activities and dams for the first time. In 1945, Congress extended the authorization for a nine-foot-deep navigation channel on the Missouri River from Kansas City, Missouri, to Sioux City, Iowa.

Flood Damage Reduction

Despite the hazards associated with the Missouri River's floodplains, the benefits of settling in them attracted settlers and resulted in increased occupancy and development in the floodplain. In the late eighteenth and early nineteenth centuries, there was no coordinated federal program for flood damage reduction structures and policies, and large floods resulted in significant losses of life and property. Congress considered flood control primarily a local responsibility until passage of the 1917 Flood Control Act, which placed flood control on equal footing with navigation within the Corps and authorized Corps flood-control programs on the Mississippi and Sacramento rivers.

In 1927, Congress passed a River and Harbor Act that authorized the Corps to conduct surveys to formulate comprehensive water development plans in several river basins (because the provisions of the surveys were described in House Document No. 308, the surveys were known as the '308 Reports'). In examining the Missouri River basin's flood-control and navigation needs, the Corps identified several major projects intended to assist in flood damage reduction and the development of the basin. There was also catastrophic flooding on the Mississippi River in 1927, which catalyzed further federal involvement in flood-control activities (Barry, 1998). The Flood Control Act of 1936 declared floods a federal responsibility and established a national flood-control policy. Following a major Missouri River flood in 1943, the Corps prepared a report to Congress proposing five major dams on the mainstem Missouri River, two on the Yellowstone River, and five on the Republican River. These flood damage reduction works would be supplemented by levees on the banks of the Missouri River from Sioux City, Iowa, to St. Louis and would complement another ten dams already authorized for construction on Missouri River tributaries (Ferrell, 1993).

Hydropower

Construction of hydropower dams began in the Missouri basin during the second half of the nineteenth century. In 1890, the Corps of Engineers was given responsibility for approving all nonfederal dams on navigable waters. The 1920 Federal Power Act shifted primary responsibility for the approval of such nonfederal dams to the Federal Power Commission after Congress rejected federal coordinated development in favor of regulated private development (Holmes and Hays, 1974). Hydropower was considered a project purpose for most Bureau of Reclamation dams, and the revenue from hydropower sales was often used to help offset funding shortfalls in irrigation repayments. The Corps was also authorized to include hydropower as a project purpose, but only as a subsidiary to flood control or navigation. Taking advantage of the hydropower potential in the upper Missouri basin, private utilities had constructed several hydropower dams on the tributaries upstream from Fort Peck.

THE PICK–SLOAN PLAN

Setting and Impetus

The most important and lasting alteration of the Missouri River ecosystem resulted from the Pick–Sloan Plan. Pick–Sloan was the product both of the Great Depression and the progressive conservation movement's belief that multiple-purpose water projects would stimulate growth in the arid West (Hays, 1999). The gospel of the progressive movement was that growth would follow the "harnessing" of rivers. The Pick–Sloan Plan also reflected the arid lands reclamation movement, which was promoted at the turn of the century by irrigation enthusiasts like George Maxwell and William Smythe.

Unsustainable agricultural practices on the Great Plains, an economic depression, and the prolonged drought in the 1930s that created the Dust Bowl focused the Bureau of Reclamation's attention on additional storage and diversions in the Missouri basin. Bureau of Reclamation engineers subsequently developed plans for three large dams on the mainstem of the Missouri River downstream from Fort Peck, Montana, as well as for dams on the Yellowstone, Niobrara, Platte, Kansas, and Upper Missouri rivers and on several of the Missouri's western tributaries. These proposed projects would irrigate more than 4 million acres in the basin, and an additional 1.4 million acres in the Souris–Red River basin (which lies northeast of the Missouri River basin) through inter-basin water transfers from the Missouri River basin. Proponents of these schemes believed that the projects would not only increase the extent of basin agriculture, but that they would also provide construction jobs for thousands of basin residents (Ferrell, 1993).

As the drought of the 1930s began, it was apparent that even with the future construction of those dams, there would be insufficient water in the Missouri River to maintain a six-foot deep navigation channel. A 1932 Corps report proposed that it build a major dam on the Missouri River at Fort Peck, Montana. The dam was intended to store water that could be released to supplement flows in the Missouri River downstream from Sioux City, Iowa (Ferrell, 1996). In 1933, Congress passed the National Industrial Recovery Act (NIRA), which authorized the President to undertake public works projects. The Fort Peck project appeared to offer an opportunity to put people in the Upper Missouri basin to work and to support Missouri River navigation. Less than four months after the NIRA was enacted, President Franklin D. Roosevelt directed construction to begin on Fort Peck Dam. By 1939, the dam, then the largest in the basin, was completed and was beginning to store a planned 19.5 million acre-feet of Missouri River water. The dam was approved to provide flow for the authorized Missouri River navigation project and, when feasible, for the development of hydropower under the auspices of the Bureau of Reclamation.

Merging the Plans of the Bureau and the Corps

The Pick–Sloan Plan was an amalgam of separate Missouri River development plans prepared by the Bureau of Reclamation and the U.S. Army Corps of Engineers. The Corps of Engineers was proceeding with plans for flood-control and navigation-enhancement dams and reservoirs under the aegis of its Missouri River Division Engineer, Colonel Lewis Pick. The Corps' plans responded to the devastating 1943 Missouri River floods and to lower basin navigation interests. The Bureau's water development planning for the Missouri River basin was the responsibility of its regional director William Glenn Sloan. The Bureau's chief goals were irrigation development and hydroelectric power generation. It proposed some ninety dams and reservoirs across the basin, along with several hundred irrigation projects covering 4.7 million acres, which would have doubled the basin's irrigated acreage (Carrels, 1999).

Both plans included several large mainstem reservoirs (Figure 2.2 shows the Pick Plan and the Sloan Plan). Both were presented to Congress at the same time that Congress was considering legislation to create a Missouri River Authority that would promote and coordinate comprehensive development. There was thus considerable pressure from President Roosevelt, basin water interests, and influential members of Congress to create a single basin development plan. The similarities between the Pick Plan and the Sloan Plan enabled the two agencies to meet in Omaha, Nebraska in October, 1944 to quickly reconcile the differences between the two plans and combine them into a unified plan. Congress settled the jurisdiction of the two agencies: the Corps would build and operate the mainstem dams and the Bureau would allocate the water dedicated to irrigation. With this and other minor adjustments, Congress ratified the Omaha agreement in the Flood Control Act of 1944, but as a Corps historian noted, "[t]he accord did not purport to deal with the policy issues that arose as project development proceeded . . . The conferees had not considered interdependence of hydropower, irrigation, navigation, and municipal and industrial water supply; nor [sic] the effects on water and related land and fish and wildlife" (Ferrell, 1993).

The Flood Control Act of 1944 also granted the Corps responsibility for flood-control structures in the lower Missouri River and its tributaries in Kansas and Missouri. The Bureau of Reclamation was to construct and operate dams on the Missouri upstream from Fort Peck Dam and on upper basin tributaries. The Corps was to determine flood-control and navigation storage capacities in all dams in the basin, and the Bureau would determine irrigation potential. Subsequently, the Fort Peck project would be operated primarily for irrigation (Ferrell, 1993). The last of Pick–Sloan's five mainstem dams (Table 2.1 and Figure 2.3) was completed in 1963 (Fort Peck Dam was completed before Pick–Sloan). In addition to the Pick–Sloan dams, the U.S. Natural Resources Conservation Service (formerly the Soil Conservation Service) has constructed hundreds of smaller water projects on the Missouri River's tributaries.

TABLE 2.1 Missouri River Reservoirs

Reservoir	Year of Dam Closure	Storage Capacity (1,000 acre-feet)
Fort Peck	1937	18,688
Fort Randall	1952	5,574
Garrison	1953	23,923
Gavins Point	1955	492
Oahe	1958	23,338
Big Bend	1963	1,874

SOURCE: USACE (1979), as amended in 1989.

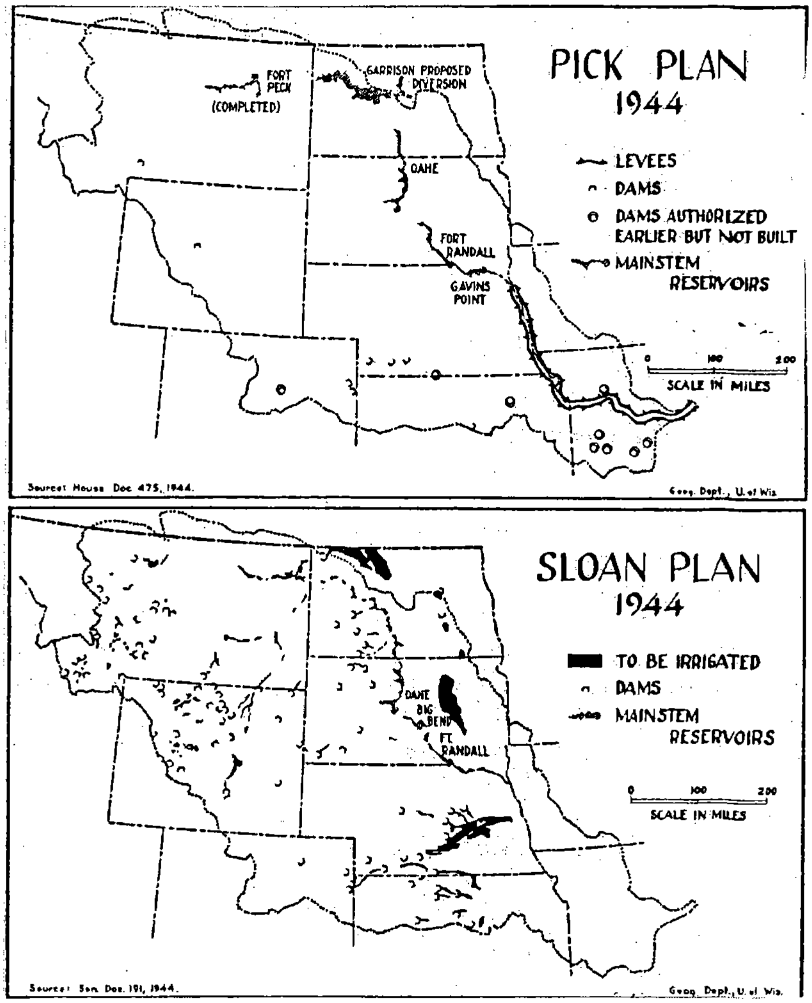

FIGURE 2.2 Proposed water projects under the Pick and Sloan Plans.
SOURCE: Hart (1957).

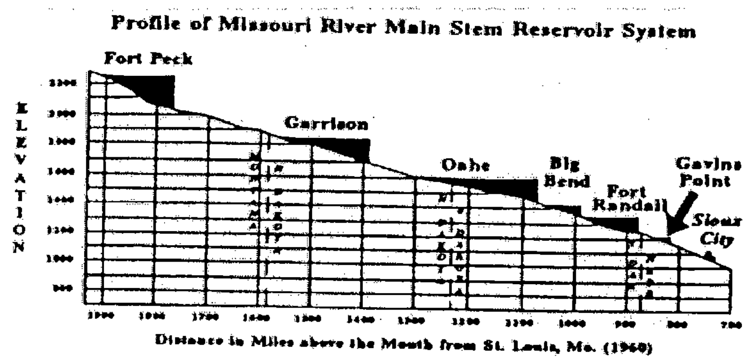

FIGURE 2.3 Missouri River mainstem dam elevations and profile.

State and Federal Governance under Pick–Sloan

When the Pick–Sloan Plan was signed, it was assumed that its authorization would be followed by a new basinwide governance organization. A Missouri Valley Authority was proposed in 1936 and again in 1944, but these proposals were strongly opposed and were never enacted (Ferrell, 1996; Ridgeway, 1955). A Missouri Basin Inter-Agency Committee (MBIAC) was formed in 1945. The MBIAC's membership included representatives from several federal agencies (Trelease (1953) listed forty-three federal agencies with some role in Missouri basin development) and five governors chosen by a Missouri River States Committee (Thorson, 1994). The MBIAC was hampered by the lack of a clear legal mandate and it was terminated in the early 1970s (ibid.).

Pursuant to Title II of the 1965 Water Resources Planning Act, the Missouri River Basin Commission (MRBC) was established in 1972 and assumed the responsibilities of the former Missouri Basin Inter-Agency Committee. Membership of the MRBC remained a mix of federal and state representatives, but it was organized with a staff and conducted planning studies at the sub-basin level, often focused on basins within a single state. The 1965 federal legislation sought comprehensive water resources planning that went beyond agency-specific efforts and that included substantial roles for basin states. Other basins in which commissions were established were in New England, the Ohio River basin, the Pacific Northwest, the Great Lakes, and the Souris-Red-Rainy area (Rieke and Kinney, 1997). However, the commissions were organized at the end of the dam building era and never developed clear missions.

MRBC members represented thirteen federal agencies, all ten basin states, the Yellowstone Compact Commission, and the Big Blue River Compact Administration (Thorson, 1994). The commission developed a management plan, published numerous reports, and established a hydrology model that supported water use monitoring and accounting within the basin. But the "commission's greatest

Box 2.1
Native Americans and Pick–Sloan

The Pick–Sloan Plan was widely supported by water interests throughout the Missouri River basin. Native American tribes, however, took a dim view of the project. The Missouri River floodplains were essential to the tribes. Although the Fort Laramie Treaty of 1851 had granted tribes a permanent homeland for their agricultural economy and culture along the Missouri River, little consideration was given to the tribes in the enactment of the 1944 legislation.

The Pick–Sloan reservoirs displaced thousands of Native Americans from their lands. The five Corps of Engineers mainstem dams displaced roughly 900 Native American families (Lawson, 1994). Tribal groups affected were the Arikaras, Chippewas, Mandans, and Hidatas of North Dakota; the Shoshones and Arapahos of Wyoming; and the Crows, Crees, Blackfeet, and Assiniboines of Montana (Lawson, 1994). In total, the Missouri River mainstem dams flooded over one million acres, much of it belonging to Native Americans (Shanks, 1974). According to Lawson (1994), "The Pick–Sloan Plan . . . caused more damage to Indian land than any other public works project in America."

All the mainstem dams in North and South Dakota, except Gavins Point Dam, flooded the Native Americans' most productive land and resulted in large numbers of ousted people. Garrison Dam submerged 155,000 acres on the Fort Berthold Indian Reservation. The reservation ended up with five isolated areas of remnant upland plains. A total of 1,700 people were relocated, which represented 289 of the tribe's 357 families. The tribe lost its winter grazing in the river bottom and 90 percent of its timber. Most of its lignite coal seams that provided heating fuel became inaccessible. Wild game, an important food source, was greatly diminished. Oahe Reservoir submerged the river bottoms of the Standing Rock and Cheyenne River reservations. 160,000 acres were covered and 351 families were relocated. Up to 90 percent of the timberland and 75 percent of the corn land were submerged. As at Garrison Dam, the tribes lost their winter grazing and their wild game food sources. Big Bend and Fort Randall dams dislocated families from the Yankton, Rosebud, Crow Creek, and Lower Brule Reservations. The dams flooded over 20,000 acres of tribal land, with 17,000 of those being inundated on the Crow Creek and Lower Brule reservations, where 120 families were relocated.

The issue of compensation for the loss of their valued floodplains has not been resolved to the tribes' satisfaction: "The tribes are still waiting for fair compensation for the lands taken, as well as water and electricity for homes on the reservation" (Thorson, 1994). Between 1947 to 1949, the tribes received \$12.6 million for their lost lands (about \$81 per acre) and various relocation costs. This level of compensation was viewed as inadequate and was partially rectified over forty later when, in 1991, Congress adopted the recommendations of the Garrison Diversion Unit Joint Tribal Advisory Committee and established a \$149 million recovery fund (Thorson, 1994).

Native Americans continue to be involved in the details of Pick–Sloan and Missouri River mainstem dam operations. For example, in October 2000 the Standing Rock Sioux Tribe sued the Corps. The suit related to concerns about the impacts of the fluctuating levels of Lake Oahe on burial sites along the shoreline. The Corps and the tribe subsequently agreed on a settlement that will provide the tribe with an opportunity to help the Corps monitor and stabilize the sites and prevent further erosion (Jehl, 2000).

accomplishment was providing a forum for communication and information sharing"(ibid.). This accomplishment did not lead to a basin-wide management regime, however, because the MRBC and the other Title II commissions were generally seen as ineffective, as they had lost their primary mission—the review and coordination of large projects for consistency with other basin resources management objectives. They were thus all terminated in 1981. Termination of the MRBC eliminated one of the important forums for frequent discussions and cooperative activities on Missouri River water management issues.

The Missouri Basin states immediately formed the Missouri Basin States Association (MBSA). As the staff addressed several ongoing studies, issues concerning the rights of states to market water outside the basin arose among the states, and the utility of the MBSA came into question. In 1986, the states attempted to develop a compact agreement, which failed because the states were unable to address all the concerns of the states, and they were unable to develop a common approach to address federal and tribal claims to water (Thorson, 1994). In 1988 the MBSA was dissolved when the basin states either concluded that it was not effective in resolving basin conflicts or was peripheral to their interests (Thorson, 1994). In 1990 the MBSA was reconstituted to fill the representation vacuum created by the dissolution, and its membership was expanded to include tribal representation. The MBSA also sought to increase its general base of support throughout the region and was renamed the Missouri River Basin Association (MRBA). Eight basin states are currently members of the association (Colorado and Minnesota currently do not participate). Members are appointed by their governors and normally are senior water management officials. In 1990, the Mni Sose Tribal Water Rights Coalition, which was formed in 1988 to assist 28 of the 29 basin tribes in securing their water interests, became a voting member of MRBA. In 1998, the MRBA attempted to mediate an agreement among the states concerning the development of new operating rules for the Missouri mainstem, but it was unable to achieve consensus.

Another organization that promotes dialogue on Missouri River management issues is the Missouri River Natural Resources Committee (MRNRC). Formed in 1987 to help promote ecological stewardship, membership of the MRNRC includes the state fish and wildlife agencies of the seven states that the Missouri River flows through or borders. The Corps, the U.S. Fish and Wildlife Service, and the U.S. Department of Energy's Western Area Power Administration (WAPA) are ex officio, non-voting members, and the U.S. Geological Survey, the Bureau of Reclamation, and the National Park Service are cooperating members.

Federal agencies with Missouri River management and science responsibilities currently meet once or twice a year on Missouri River issues under the auspices of a Missouri River Roundtable (Box 2.2 lists federal agencies with water science and management roles in the basin). Roundtable meetings focus on identifying prospective collaborative efforts, and they provide members the opportunity to share information on relevant activities. Roundtable members have mutually agreed to avoid areas of conflict and focus on areas of cooperation.

The net result of the inability of the states and federal government to develop an effective basinwide governance structure is that the Missouri River is currently managed

Box 2.2
U.S. Water Resources Management and Science Organizations in the Missouri River Basin

Army Corps of Engineers—Responsible for flood-damage-reduction activities and navigation-enhancement activities; also involved in ecosystem restoration activities. The Corps constructed and operates thousands of dams across the nation, and it constructed and operates six mainstem dams on the Missouri River.

Bureau of Reclamation—Responsible for water resources development and management activities in the 17 western (contiguous) U.S. states (i.e., those that straddle the one-hundredth meridian and westward). The Bureau constructed and operates the Canyon Ferry Dam on the Missouri River, along with many other dams across the western United States.

Environmental Protection Agency—Water-related responsibilities include establishing drinking water quality standards, wastewater management, and wetlands, oceans, and watersheds. EPA jointly administers (with the Corps of Engineers) the Clean Water Act's Section 404 program. EPA also monitors progress of national programs for total maximum daily load pollutants and for reducing nonpoint source pollution.

Federal Emergency Management Agency—Administers the National Flood Insurance Program, which provides flood insurance to communities that agree to assure that future floodplain structures meet safe standards. FEMA also conducts other flood hazard mitigation, response, and recovery activities.

Federal Energy Regulatory Commission—Responsible for reviewing, relicensing, and decommissioning federally licensed hydroelectric power dams.

Fish and Wildlife Service—Major responsibilities involve migratory birds, endangered species, certain marine mammals, and freshwater and anadromous fish. A major function is the identification and recovery of endangered species. Under the Endangered Species Act, the Service identifies species that appear to be endangered or threatened. The Service consults with other federal agencies and renders "biological opinions" on the effects of proposed federal projects on endangered species.

Forest Service—Manages federal "Wild and Scenic rivers," manages national forest lands to promote watershed protection.

Geological Survey—Conducts scientific programs in several areas of water resources, including streamflow gauging, groundwater monitoring, water quality assessment (the USGS oversees the National Water Quality Assessment Program, or NAWQA), and ecosystem monitoring through its Biological Resources Division.

National Park Service—Has regulatory and planning responsibilities on National Park lands. The Missouri basin contains dozens of national parks and national monuments.

Natural Resources Conservation Service (formerly the Soil Conservation Service)—Promotes land-use management practices aimed toward reducing erosion and promoting conservation. NRCS seeks to reduce the risks of floods and droughts in the nation's watersheds.

Tribal Governments—Native American tribes have federal public trust rights and responsibilities on their reservations. The Mni Sose organization represents 28 of the Missouri Basin's Native American tribes in basinwide water policy discussions and formulation.

Western Area Power Authority—Markets and delivers hydroelectric power and related services within a 15-state region of the central and western United States, including most of the Missouri River basin. WAPA, one of four power marketing administrations within the U.S. Department of Energy, markets electricity from Bureau of Reclamation and Corps of Engineers hydropower dams.

almost exclusively by the Corps of Engineers according to the Flood Control Act of 1944 (which includes the Pick–Sloan Plan).

Pick-Sloan had two major consequences for Missouri River management decisions. First, it dedicated upstream storage to three primary uses: hydropower generation, navigation enhancement, and flood control. Second, it made the Corps the de facto mainstem river master and reduced the influence of other federal agencies in mainstem management issues. The act's key provisions included:

a. declared the Congressional policy to recognize rights and interests of states in water resources development and the requirement for consultation and coordination with affected states.
b. required the Corps to coordinate with the U.S. Department of the Interior in cases of waters rising west of the ninety-seventh meridian.
c. authorized provision of recreation areas for public use, including recreation and fish and wildlife conservation.
d. assigned the Secretary of the Army responsibility for prescribing use of storage allocated for flood control or navigation in all reservoirs constructed wholly or in part with federal funds, and
e. authorized the Corps to include irrigation as a project purpose in the 17 western states.

The Act also includes the following language inserted by Senators Joseph O'Mahoney (Wyoming) and Eugene Millikin (Colorado) that guarantees the upper basin states a priority to use water for irrigation:

> The use for navigation, in connection with the operation and maintenance of such works herein authorized for construction, of waters arising in States lying wholly or partly west of the ninety-eighth meridian shall be only such use as does not conflict with any beneficial consumptive use, present or future, in States lying wholly or partly west of the ninety-eighth meridian, of such waters for domestic, municipal, stock water, irrigation, mining, or industrial purposes. (33 U.SC. 701-1.)

Since approval the Flood Control Act of 1944, the Corps has operated the mainstem system in accordance with its understanding of competing needs in the basin, its responsibilities described in navigation and flood-control legislation, and in response to congressional committee instructions. Although the Bureau of Reclamation initially sought to establish a centralized basin-control system, it eventually acceded to Corps control because its proposed reclamation agenda had not been realized. Only the responsibility for tributary operations was left to the agency responsible for specific project construction. As the mainstem dams were completed and their reservoirs filled, the Corps assigned operation of the system to its Reservoir Control Center in Omaha, Nebraska, where it remains today.

In 1953, to provide opportunities for coordination with the states and the other federal agencies, the Corps established a Coordinating Committee on Missouri River Mainstem Operations. This committee functioned for nearly three decades. In 1982, because the newly passed Federal Advisory Committee Act (FACA) created administrative requirements for the committee's operation and limited its ability to operate in executive session, and therein to forge consensus positions, the committee agreed to dissolve. The Corps announced that in place of the committee it would conduct semiannual public meetings to provide information about important

water development issues. The Corps has also solicited comments on proposals for changes to dam and reservoir operations.

Since Pick–Sloan, the Corps has emerged as the Missouri River water master, although the river must be managed in the context of a larger suite of federal, state, and tribal laws. The Corps' role as the key federal agency in Missouri River management has been facilitated because there are relatively few private or public entitlements on the mainstem which conflict with its policies. No private individual or state "owns" the flow of the Missouri. Each basin state can claim an equitable share by Supreme Court degree, interstate compact, or Congressional action, but the Missouri has never been apportioned by any of these methods. The federal "navigation servitude" posits that no individual may assert a property right to the flow of a navigable river below the high water mark, but private entities and tribes may obtain a right to use a portion of the flow (individual water rights are described in Box 2.3). Because firm private and tribal rights exist primarily on the tributaries (with the exception of Montana), the Missouri is most accurately characterized as a regulated river, rather than a fully allocated one.

Box 2.3
Water Rights in the Missouri River Basin

State Use Entitlements. Each riparian state is entitled to an equitable share of the river, but the right must be based on prior or reasonably anticipated use. The rights can be firmed up by Supreme Court decree, interstate compact, or congressional apportionment. The states have explored these options, but they have not been implemented. In the 1980s, the Supreme Court rejected an original action that asserted that the Pick–Sloan Plan was a congressional apportionment. Article III, Section 2 of the U.S. Constitution provides that suits by one state against another state must be filed directly in the Supreme Court rather than in a lower federal court. In practice, the Supreme Court appoints a special master to take evidence and prepare a recommended decision, and the Court hears arguments bythose who object to the special master's report.

Individual Use Rights. Colorado, Montana, North Dakota, South Dakota, and Wyoming follow prior appropriation and allow an individual to perfect a right based on diversion and application to beneficial use. The states of Iowa and Missouri recognize common law riparian rights and permit rights. Riparian rights exist by virtue of ownership of land adjacent to a stream and do not depend on actual use. Kansas is now a pure appropriation state. Nebraska is a dual state and recognizes both riparian and appropriation rights.

Rights of Indian Tribes. Indian tribes may claim group rights that have both riparian and appropriative characteristics. Based on the Winters Doctrine of 1908, federal reserved water rights arise by virtue of the creation of a reservation. These rights date from the date of the creation of the reservation (or perhaps time immemorial if they are true aboriginal rights) and do not depend on the application of water to beneficial use. However, the rights have been primarily recognized for irrigation and have not been of great benefit to the Missouri River tribes.

Regulatory Rights. The federal government can mandate flows for environmental protection purposes. These flows supercede state-created water rights.

Navigation Rights. The "navigation servitude" posits that no individual may assert a property right to the flow of a navigable stream below the stream's high-water mark. The assumption has long been that the government may enhance or destroy the navigable capacity of a stream. In a February 1988 decision (ESTI Pipeline Project v. Missouri, 484 U.S. 495, 1988), the Supreme Court gave the

Corps great discretion to make decisions about Missouri River flow management. However, the status of navigation is complicated by the O'Mahoney–Millikin compromise, which the upper basin states argue subordinates navigation to irrigation and precludes the recognition of any vested rights for a navigation channel depth.

Flood Protection Rights. The federal government is not liable for "acts of God" and is immune from all liability arising from the operation of flood-control reservoirs (33 U.S.C. Section 702c). This committee was not aware of any case alleging that the federal government is liable for flood damage when it subordinates flood control to environmental protection objectives. The assumption is that if the government inundates land above the high-water mark in connection with a flood-control project, the government must compensate the landowner. But this assumption must be qualified.

The Supreme Court recently limited the federal government's immunity for flood damage. Immunity is now based on the function of the release that did the damage rather than on the source of the release. Thus, if the water is released from a multiple-purpose reservoir for a non-flood control objective such as irrigation, the federal government will be liable for the resulting *damage* (Central Green Co. v. United States, 531 U.S.____ 1999). This decision opens the possibility that land owners injured by reservoir releases unrelated to any flood-control objective may recover damages from the federal government.

KEY DEVELOPMENTS FOLLOWING PICK–SLOAN

Pick–Sloan was enacted at the height of the Reclamation Era, before the project's environmental consequences were clearly understood and before the environmental movement of the 1960s. Many fish and wildlife professionals understood the possible adverse consequences of dams for fish. As early as 1934, Congress enacted the Fish and Wildlife Coordination Act, which mandated that fish conservation be given equal treatment with other project purposes. However, the 1934 act did not substantively influence dam construction or operation, except to provide the legal basis for fish ladders and stocking programs. Beginning in 1969, Congress began to enact a series of environmental protection laws that imposed new duties on federal water resources management agencies.

Three key laws require the incorporation of environmental values into dam and reservoir operations. The National Environmental Policy Act of 1969 requires the preparation of environmental impact statements (EIS) for all major federal actions that will significantly affect the quality of the environment. This act has been interpreted as to not apply to pre-1969 dam operating plans [Upper Snake River Chapter of Trout Unlimited v. Hodel, 706 F. Supp. 737 (D. Idaho 1989), aff'd, 921 F. 2d 232 (9th cir. 1990)]. But new actions such as the preparation of new operating guidelines, structural changes to a dam or power plant, are likely to trigger a full environmental impact statement on operations, as compared to simply the existence of the dams.

The Clean Water Act of 1972 imposes technology-forcing standards on all point sources of pollution. An important federal circuit court appeals decision held that dams were not point sources [National Wildlife Federation v. Gorsuch, 693 F. 2d 156 (D.C. Cir. 1982)], but this case is not likely the last word on the issue.

The Endangered Species Act of 1973 has the greatest potential to mandate changes in dam and reservoir operations. Unlike NEPA, the mandates of the statute are substantive rather than procedural. The act permits the Department of the Interior to list species as endangered or threatened. Once a species is listed, no federal agency may take an action that jeopardizes the continued existence of the listed species or that modifies its critical habitat. Specifically, the federal agency must consult with the U.S. Fish and Wildlife Service. If the U.S. Fish and Wildlife Service decides that the federal action is likely to jeopardize the continued existence of the species, it will prepare a biological opinion, which documents the likely impacts of the action and suggests reasonable and prudent alternatives and possible mitigation measures. In practice, the consultation process has turned into a permit process rather than a veto process over federal actions. Nonetheless, the Endangered Species Act is both an important consideration in water management decisions and an additional source of discretion for altering traditional water management policies.

The Master Manual

The impacts of NEPA, the Clean Water Act, and the Endangered Species Act are reflected in the current controversy over proposed revisions to the Corps' Missouri River Main Stem System Reservoir Regulation Manual (Master Manual), which was first prepared in 1960 by Corps staff in Omaha. The Master Manual is the primary guidance document for operation of the mainstem reservoirs and reflects the Corps' interpretation of its statutory responsibilities and operating approaches developed in coordination with state agencies and other federal agencies. The Master Manual codified the practices that had developed over the previous decade (Ferrell, 1993). Although it does not define specific operating priorities, the Master Manual does provide general guidance for dealing with conflicts among uses (section 9-3):

> The following general approach which was developed and generally agreed upon during planning and design of the reservoirs, is observed in operation planning and in subsequent reservoir regulation procedures:
>
> First, flood control will be provided for by observation of the requirement that an upper block of this intermediate storage space in each reservoir will be vacant at the beginning of each year's flood season, with evacuation scheduled in such a manner that flood conditions will not be significantly aggravated if at all possible (this space is available for annual regulation of flood control and all multiple purpose uses but should be vacant at the beginning of each flood season).
>
> Second, all irrigation and other upstream water uses for beneficial consumptive purposes during each year will be allowed for. This allowance also covers the effects of upstream tributary reservoir operations, as anticipated from operating plans for these reservoirs or from direct contact with operating agencies.
>
> Third, downstream municipal and industrial water supply and water quality requirements will be provided for.
>
> Fourth, the remaining water supply available will be regulated in such a manner that the outflow from the reservoir system to Gavins Point provides for equitable service to navigation and power.

Fifth, by adjustment of releases from the reservoirs above Gavins Point, the efficient generation of power to meet the area's needs consistent with other uses and power market conditions will be provided for.

Sixth, insofar as possible, without serious interference with the foregoing functions, the reservoirs will be operated for maximum benefit to recreation, fish and wildlife.

To supplement the Master Manual, the Corps each year prepares a more detailed Annual Operating Plan (AOP). During its existence, the Coordinating Committee on Missouri River Mainstem Operations provided input to the Annual Operating Plan. Since then, semiannual public meetings provide opportunities for public and governmental input.

MISSOURI RIVER RESERVOIRS AND DAMS
Dam and Reservoir Operations

The Missouri River mainstem reservoir system consists of six major dams and reservoirs (Photos 2.1 through 2.6). The reservoirs differ greatly in storage and discharge capacity, shoreline length, and drainage area characteristics (Table 2.2).

PHOTO 2.1. Fort Peck Dam (from Corps of Engineers Digital Visual Library http://images.usace.army.mil/)

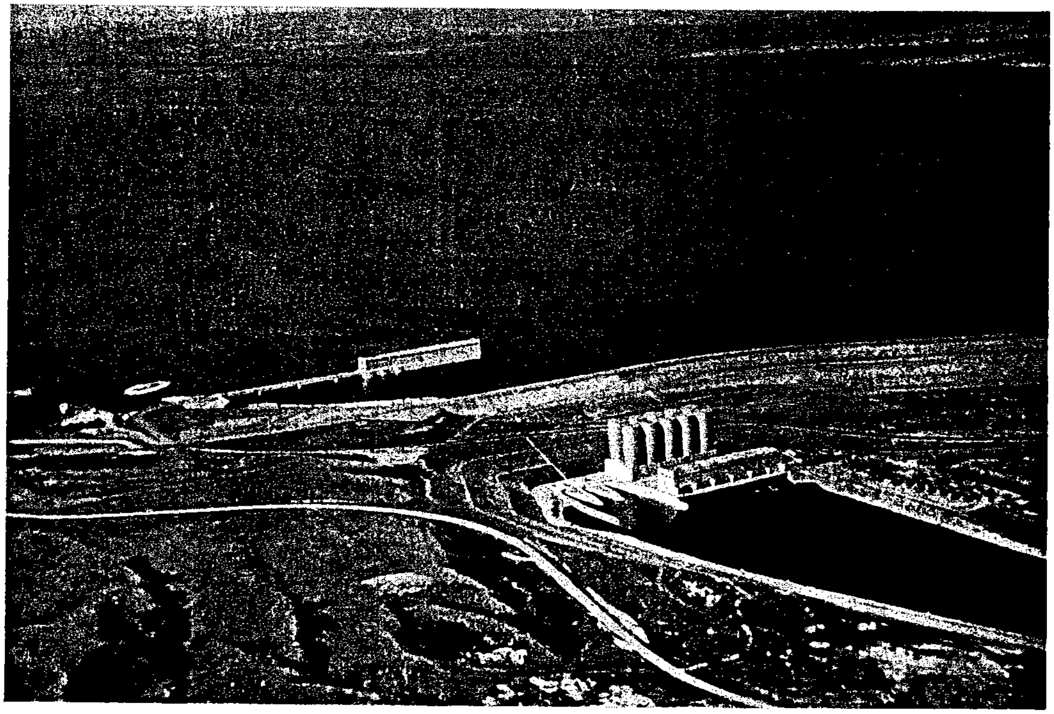

PHOTO 2.2. Garrison Dam (from Corps of Engineers Digital Visual Library)
http://images.usace.army.mil/

PHOTO 2.3. Oahe Dam (from Corps of Engineers Digital Visual Library)

PHOTO 2.4. Big Bend Dam (from Corps of Engineers Digital Visual Library *http://images.usace.army.mil/*)

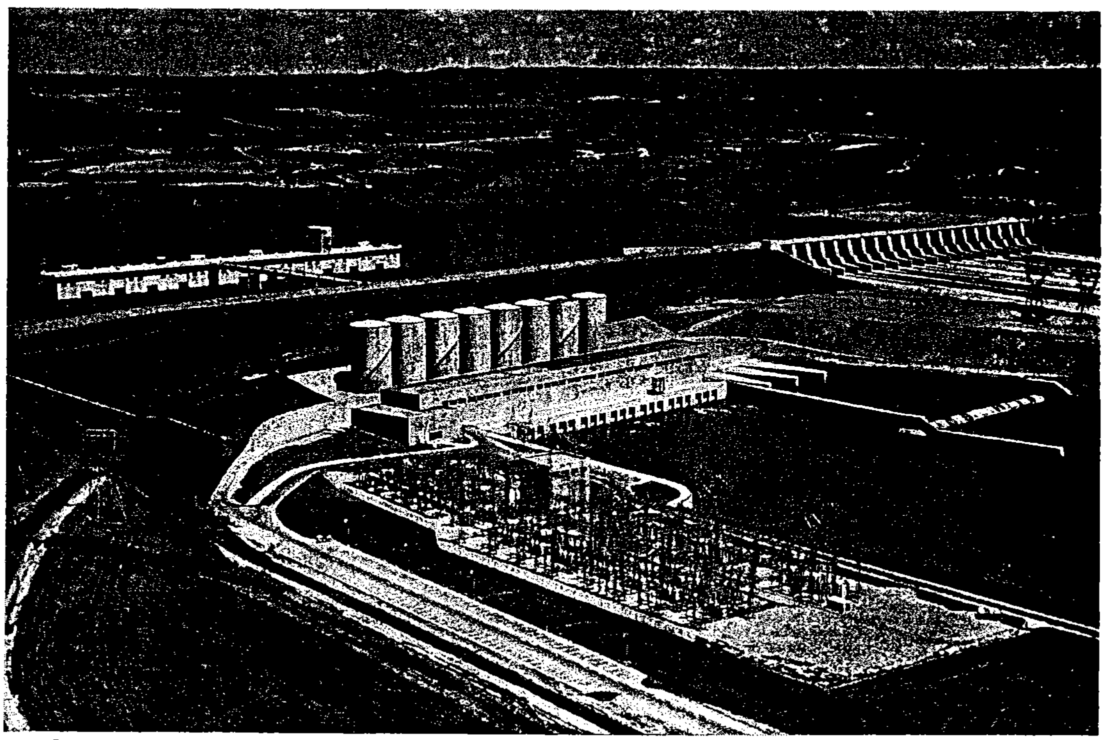

PHOTO 2.5. Fort Randall Dam (from Corps of Engineers Digital Visual Library http://images.usace.army.mil/)

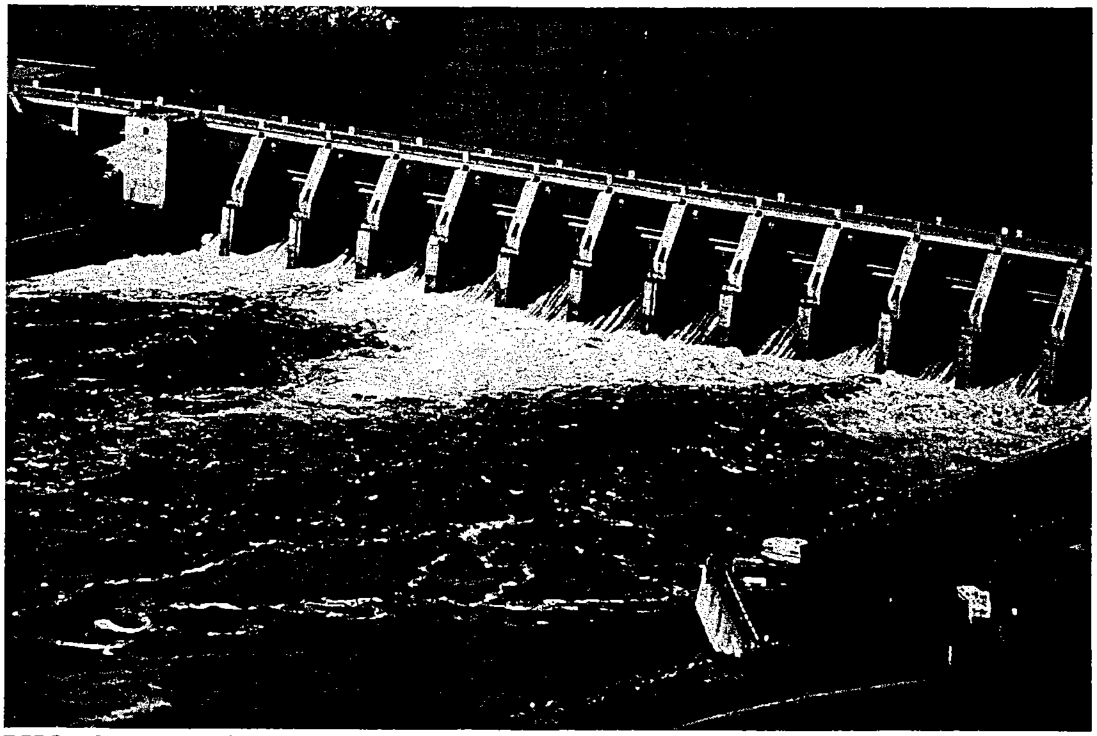

PHOTO 2.6. Gavins Point Dam (from Corps of Engineers Digital Visual Library http:/images.usace.army.mil/)

Reservoir (1)	Storage capacity (1,000 acre-feet) (2)	Maximum discharge capacity (cubic feet per second) (3)	Lake shoreline length (miles) (4	Cumulative drainage area upstream (square miles) (5)	Cumulative average annual inflow upstream (cfs) (6)
Fort Peck Lake	18,688	291,000	1,520	57,500	10,200
Garrison Dam / Lake Sakakawea	23,923	796,000	1,340	181,400	25,600
Oahe Dam / Lake Oahe	23,338	245,000	2,250	243,490	28,900
Big Bend Dam / Lake Sharp	1,874	373,000	200	249,330	28,900
Fort Randall Dam / Lake Francis Case	5,574	680,500	540	263,480	30,000
Gavins Point Dam / Lewis and Clark Lake	492	381,000	90	279,480	32,000

TABLE 2.2. Missouri River reservoir features.
SOURCE: USACE, 1989

For purposes of reservoir management, modeling, and decision-making, these reservoirs are divided into different conceptual levels, or zones. Figure 2.4 shows these conceptual zones, how they are divided according to the authorized uses in the system, and the capacities of each. Table 2.3 shows more detailed information about the capacities of these zones in the six mainstem reservoirs operated by the Corps.

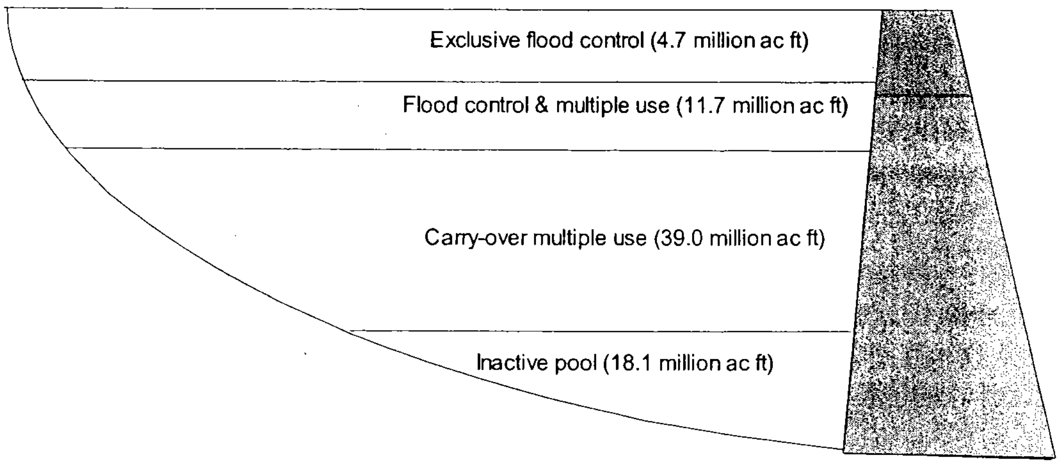

FIGURE 2.4. Missouri River system reservoir storage allocation (values shown represent cumulative capacity of the six main-stem reservoirs)
SOURCE: USACE, 1989

TABLE 2.3. Missouri River Reservoir Operational Zones

Zone (1)	Use[1] (2)
Exclusive flood control	...top zone in each reservoir...utilized only for detention of extreme or unpredictable flood flows, and is evacuated as rapidly as feasible within limitations imposed by considerations for flood control...[which] include project release limitations, status of storage in other main stem projects and the level of system releases being maintained...
Flood control and multiple use	...reserved annually for retention of normal flood flows and for annual multiple-purpose regulation of the impounded flood waters...this zone...will normally be evacuated to a predetermined level by about 1 March to provide adequate storage capacity for the flood season...evacuation of the flood control and multiple use storage capacity is scheduled to maximize service to the conservation functions.
Carry-over multiple use	...provides a storage reserve for irrigation, navigation, power production, and other beneficial conservation uses. At the major projects (Ft. Peck, Garrison and Oahe) the storage space in this zone will provide carry-over storage for maintaining downstream flows [for] below normal runoff years. It will be used to provide annual regulation in the event the storage in the annual flood control and multiple-use zone is exhausted.
Inactive	...provides minimum power head and sediment storage capacity. It also serves as a minimum pool for recreation, fish and wildlife, and assured minimum level for pump diversion of water from the reservoir...drawdown into this zone will not be scheduled except in an unusual emergency.

SOURCE: USACE (1979)

Authorized purposes for these reservoirs include:

- *Flood Damage Reduction.* The high-risk season for flooding in the Missouri River system, March until mid-summer, coincides with the potential occurrence of snowmelt, ice jams, or heavy rainstorms. The Corps divides the storage capacity of each reservoir into zones, or pools (Figure 2.4), and reserves space in each reservoir for flood control. Table 2.4 shows the flood control storage volume reserved in each reservoir, and also shows additional reservoir storage in the system allocated for other project purposes.
- *Water Supply and Irrigation.* One of the authorized purposes of the mainstem reservoir system is to supply water for municipalities, industries, and irrigation throughout the basin. Irrigation was an integral component of the original system planning and design, pumps, diversions, and other water distribution facilities were planned and constructed to move water to farms in the basin. However, as Sveum (in Benson, 1988) noted, "lack of support and economic problems" have resulted in less than anticipated demand for water from Lake Sakakawea (Garrison Diversion Unit) and from the irrigation development at Oahe Dam. The latter was de-authorized and the former is not in full operation. Downstream from Sioux City, Iowa, 40 major municipal and industrial users depend on the Missouri River for water. Seventeen of the 40 users are municipalities that withdraw water for approximately 3.2 million people, 21 are power plants that withdraw water for cooling, and 2 are chemical manufacturers (GAO, 1992).
- *Navigation.* The Missouri River navigation channel extends 735 miles upstream from the river's mouth at St. Louis to Sioux City, Iowa. The Corps of Engineers' Navigation Data Center reports that total downbound shipping in 1999 was 4.29 million tons and upbound shipping was 4.72 million tons (http://www.wrsc.usace.army.mil/ndc/). Shipping is seasonal and it typically extends from late March until late November or mid-December. During the remainder of the year, the possibility of ice blockage and floating ice prevents commercial navigation. Releases are made from the system reservoirs to support navigation. Fort Peck, Garrison, and Oahe dams provide about 88 percent of the total water storage capacity and thus play a significant role in supporting navigation. The multiple use zones in the reservoirs store water from year to year to support navigation when water in the annual operating zone is exhausted.
- *Hydropower.* All reservoirs have facilities for hydropower generation, and the sale of the energy is a major revenue-producing system purpose. Installed power generation capacity of the reservoirs is shown in Table 2.5. The Western Area Power Administration markets and transmits the power generated by the Missouri River reservoir system.

TABLE 2.4. Flood control storage in Missouri River system reservoirs

Reservoir (1)	Exclusive flood control storage (1,000 ac ft) (2)	Flood control and multiple use storage (1,000 ac ft) (3)
Fort Peck	974	2,718
Garrison	1,494	4,220
Oahe	1,097	3,186
Big Bend	60	117
Fort Randall	985	1,322
Gavins Point	60	92

- SOURCE: USACE, 1989

TABLE 2.5. Hydropower generation capabilities of Missouri River main-stem reservoirs

Reservoir (1)	Dependable capacity (kW) (2)	Average annual energy (10^6 kWh) (3)
Fort Peck	181,000	1,044
Garrison	388,000	2,354
Oahe	534,000	2,694
Big Bend	497,000	1,001
Fort Randall	293,000	1,745
Gavins Point	74,000	700

SOURCE: USACE, 1989

- Fish and Wildlife. The Master Manual requires that ". . . the reservoirs will be operated for maximum benefit to recreation, fish and wildlife" to the extent possible, without interference with other project purposes. The manual acknowledges that fish production and development below the main stem projects are affected by reservoir levels and releases and makes provisions for operation of selected reservoirs to improve fishery resources. For example, the Corps reported that on April 28, 2000, releases at Garrison Dam were reduced from 20,000 to 18,000 cubic feet per second to keep the reservoir level from falling during the smelt spawning period (Joe Pletka, U.S. Army Corps of Engineers, personal communication, 2001). Even though the inflow into upstream reservoirs was at that time well below normal, this regulation provides for stable pools at both Lake Oahe and Lake Sakakawea. Similarly, the Master Manual acknowledges a need to operate the reservoirs for improving migratory waterfowl habitat.
- Recreation. Public Law 78-534 or Public Law 99-662 authorize operation of the mainstem reservoirs for recreation. The Corps' Summary of Actual 1999–2000 Operations report shows that during fiscal year 2000, public use at the mainstem lakes

was more than 60 million visitor hours. Recreational uses are particularly important at lakes Sakakawea, Oahe, Francis Case, and Lewis and Clark.

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Operational Procedures

Operational guidelines

The system reservoirs are operated following guidelines in a set of six individual reservoir regulation manuals and in the Master Manual. The individual reservoir regulation manuals describe how features of each reservoir that are not common to the system as a whole are to be operated, while the Master Manual prescribes the allocation of water and storage among the system's hydraulically interconnected reservoirs.

Interpretation and Operation According to Guidelines

The Reservoir Control Center (RCC) of the Corps' Northwestern Division in Omaha, Nebraska is responsible for interpreting the Master Manual guidelines and transforming the guidance into daily decisions about appropriate amount of water to release and store in the system's reservoirs. System operation is guided by the Master Manual on two time scales:

- *A seasonal scale* stipulates storage and discharge targets for system water control. In terms of serving navigation, for example, the Master Manual stipulates that if the cumulative system storage as of March 15 each year is 54.5 million acre-feet or more, then the coordinated system should be operated to provide an average flow of 31,000 cubic feet per second at Sioux City, Iowa between March 23 and November 22 (USACE, 1979). Further, the seasonal guidelines require cumulative storage to be examined on July 1 each year to determine if the navigation season should be shortened. For example, if the cumulative storage on July 1 is 25 million acre-feet or less, support of the navigation season will terminate on September 7, rather than on November 22. Similar guidance in the Master Manual stipulates minimum daily flow requirements to maintain suitable downstream water quality each month at Sioux City, minimum releases for water supply, and so on.
- *A daily-hourly scale* determines actual storage and discharge values as a function of current availability and demands. Although the Master Manual provides guidance for system and individual reservoir operations, the Corps' Reservoir Control Center staff in Omaha determines individual dam releases for all daily purposes, (or in the case of flood operations, hourly), based upon current conditions and projected inflow in the short term. For example, the Master Manual calls for operation immediately following a flood with the following priorities:

1. Evacuation of surcharge storage from all reservoirs;
2. Evacuation of exclusive flood-control storage in Lewis and Clark, Francis Case, and Sharpe lakes;
3. Evacuation of exclusive flood-control storage in Fort Peck, Sakakawea, and Oahe lakes;
4. Evacuation of annual flood-control and multiple-use storage in Lewis and Clark and Francis Case lakes' annual flood-control and multiple-use storage space above elevation 1360;
5. Evacuation of annual flood-control and multiple-use storage in Fort Peck, Sakakawea, and Oahe lakes.

But even with such specificity, actual releases and storages are not prescribed outright by the Master Manual or individual reservoir regulation manuals. Instead, the Reservoir Control Center staff reviews, on a daily or hourly basis, forecasts of future rainfall and runoff and observations of current conditions in the basin (including current storages and releases, uncontrollable inflows to the river in reaches between reservoirs, and current flooding at critical points). They then select actual releases to be made. This is complicated by the inability to perfectly forecast future inflows, and further complicated by the hydraulic interconnections of the reservoirs, as any outflow from an upstream reservoir is inflow to a downstream reservoir. The problem is thus not a simple problem of accounting for the inflow to, outflow from, and change in storage in a single reservoir. Instead, it is a problem of simultaneously finding the outflows from all reservoirs in the system to best achieve the system operation objectives—a set of objectives that is the subject of much disagreement.

The drought of the late 1980s stretched the Corps' ability to meet the variety of mainstem water demands, and the Corps ultimately decided to review the Master Manual. At the same time, the Missouri River basin states expressed concerns over priorities being assigned by the Corps to various water uses. Recreation and fish and wildlife interests argued that priority in water use for a dwindling navigation program was at their expense and represented an anachronism. The U.S. Fish and Wildlife Service asked the Corps to more carefully consider threatened and endangered species in its operations. As a result, the Corps in 1989 announced that it would conduct a major review of the Master Manual. 13 thirteen years later, this review is still underway. Several proposals have been offered by the Corps but have been quickly rejected by one or more of the interested parties.

In 1989, the Corps and the U.S. Fish and Wildlife Service began a series of consultations mandated by the Endangered Species Act. In 1990 and 1994, the Fish and Wildlife Service issued biological opinions indicating that actions proposed by the Corps would place certain species in jeopardy. On receipt of these opinions, the Corps continued to develop alternative approaches to system operations. In April 2000, the Corps requested the Fish and Wildlife Service to formally consult on the operations of the Missouri River mainstem system, related operations of the Kansas River tributary reservoirs, and on the operations and maintenance of the Missouri River Bank Stabilization and Navigation Project. The Fish and Wildlife Service concluded that continuation of current operations on the Missouri River was likely to jeopardize the continued existence of several listed species. In November 2000, the Corps' Northwestern Division Engineer discussed the Corps position on the biological opinions of the Fish and Wildlife Service:

> There is significant agreement between the Corps and Service on the known biological attributes necessary to recover the listed species . . . The Corps is absolutely committed to its role in recovery of the listed species but we also have an obligation to support other project purposes . . . Our initial assessment is that elements of the biological opinion slightly increase the risk of flooding and are detrimental to navigation. As we develop our implementation plan we will evaluate the impact of the reasonable and prudent alternative on these and other project purposes. It is possible that the Corps will propose an alternative that meets the biological objectives with reduced impacts in other areas (Strock, 2000).

The consultation continued at this report's preparation.

The Corps' historic response to the consequences of its reservoir operations on fish and wildlife habitat has been to mitigate these consequences through a variety of means including habitat acquisition and restoration, enhancement of flows through side channels, and development of backwater areas.

COMMITTEE COMMENTARY

Water resources development activities in the Missouri River basin started nearly two centuries ago, soon after the Lewis and Clark expedition. These activities occurred when a national objective was to develop the natural resources of the western United States and to promote settlement. The Missouri River and its floodplain provided water supply, food sources, fertile agricultural lands, and a transportation corridor. Huge floods that resulted in losses of life and property were typical of the pre-regulation Missouri River.

During the nineteenth century, there was an emphasis on encouraging people to settle in the Missouri River basin and other parts of the west. The promotion of irrigation thus became a national policy that was reflected in federal laws such as The Homestead Act of 1862 and the Reclamation Act of 1902. Native Americans were given little or no consideration in the political planning processes for Missouri River development.

The Great Depression of the 1930s and a pronounced drought in the Midwest and Great Plains during this period had major impacts on the basin. The Fort Peck Dam was built as a Public Works Administration project to provide jobs and to promote navigation. At the same time, the Bureau of Reclamation was planning and developing irrigation and hydropower projects on Missouri River tributaries. During the same period, the Corps was considering flood-control dams for the basin. After congressional approval of the Pick–Sloan Plan, the Corps built five mainstem dams and assumed principal responsibility for operating them.

The chain of Missouri River reservoirs and dams from Montana to South Dakota is one of the twentieth century's engineering marvels. The dams' modernistic architecture and their powerhouses testify to what was once a nearly unlimited faith in the ability of technology to bring progress to society. Pick–Sloan reflected the then almost universal faith in large dams to support and sustain regional development in areas not favored by climate and geography, and also not favored by the era's unique political and social conditions. The Great Depression of the 1930s revived the construction of multiple-purpose dams begun during the Progressive Conservation Era in the first two decades of the century. Hopes of settling returning World War II veterans on family farms in the upper basin and the need to provide civilian jobs for the veterans excited planners and politicians. The merging of the Corps' and the Bureau of Reclamation's plans into the final Pick–Sloan Plan in a sense represented a marriage contract between two of the world's most powerful water development agencies. Over the next two decades, much of the Pick–Sloan Plan was implemented to help realize a powerful vision, but one that was not fully attained. The dams and reservoirs only partially fulfilled their promise. Many citizens today are thus calling for a more comprehensive and balanced vision of the river's role in the basin.

The legal framework for the Missouri also changed with the emergence of environmental protection as a national goal. Virtually all of the nation's environmental laws have been enacted since the initial decisions were made on Missouri River mainstem dam operations and priorities. Specific examples include the strengthened Fish and Wildlife Coordination Act of 1958, the National Environmental Policy Act of 1969, and the Conservation, Protection, and Propagation of Endangered Species Act of 1973. When the mainstem dams were constructed, there was minimal consideration of environmental impacts. Since then, there has been a shift in emphasis in the United States from the development of water resources to better management of water resources in highly developed, mature systems like the Missouri River, and specifically to explore the prospects for restoring some level of ecosystem benefits that have often been diminished with river regulation. As there have also been large social and economic changes in the Missouri Basin over the past half-century, there is a clear need for a comprehensive review of operational priorities of the Missouri River dams that better reflects twenty-first century values and scientific knowledge.

The lack of a well-structured, flexible, and updated mechanism for coordinating the current interests of the Missouri River basin states, tribes, federal and state agencies, and nongovernmental parties with stakes in dam and reservoir operations represents a barrier to resolving differences and improving environmental and operational conditions. The inability of basin stakeholders to reach consensus has made it difficult to arrive at an approach to river operations that will meet contemporary and future needs in the basin. This matter must be addressed in order to preserve the Missouri River ecosystem and to provide for a broader range of ecosystem benefits that the river historically provided.